

# A revision of the British species of the genus *Phthiracarus* Perty, 1841 (Cryptostigmata : Euptyctima)

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## Synopsis

A detailed account is presented of the external morphology of the British representatives of the genus *Phthiracarus*. The literature relating to the genus is reviewed and the status of certain of the older species considered. Thirteen British species, seven of which are considered to be new, are described, figured and keyed. Of these, only *P. affinis* (Hull), *P. anonymum* Grandjean and *P. murphyi* Harding were known previously from the British Isles, while *P. laevigatus* (C. L. Koch), *P. nitens* (Nicolet) and *P. tardus* Forsslund are recorded for the first time. A neotype for *P. affinis* is designated. On the basis of the chaetotactic pattern of the legs it is suggested that the genus could be divided into two species groups.

## Introduction

The genus *Phthiracarus* comprises free-living ptychoid mites occurring predominantly in the upper layers of highly organic forest soils. Containing about 70 nominate species (see Appendix 1), it is the largest of the Euptyctimoid genera and in many respects the most difficult to study. Apart from *P. anonymum* Grandjean and certain of the more recently described species (notably *P. murphyi* Harding), the original descriptions have been somewhat superficial and it is even doubtful whether some of the nominate species listed in Appendix 1 have been correctly assigned to *Phthiracarus*. Partial revisions of the genus have been published by Jacot (1930, 1936, 1938 & 1939), Feider & Suciú (1957) and van der Hammen (1963 & 1964) but only two of the species redescribed, namely, *P. laevigatus* (C. L. Koch) and *P. nitens* (Nicolet), can now be positively identified. The only substantial keys to the genus are those published by Willmann (1931), Sellnick (1960), and Gilyarov & Krivolutsky (1975), all of which employ characters that have proved generally to be useless for species differentiation.

## Materials and methods

This revision is based on a comprehensive survey of the literature and detailed morphological studies of all the available *Phthiracarus* material from widely separated areas in the British Isles. A large part of the material was taken from the unnamed and unsorted collections of the British Museum (Natural History). Additional material was obtained from a series of fermentation and humus layer samples collected under stands of beech, larch, oak, Scots pine and Sitka spruce at the following four areas: The Woburn Estate, Bedfordshire; New Forest, Hampshire; Tintern Forest, Monmouthshire; Alice Holt Forest, Surrey. These four areas were sampled during the period April 1972 to October 1973 as part of a study designed to compare the effects of hardwood and coniferous tree species on populations of Euptyctima and full descriptions of the sampling sites will be published elsewhere. The mites were extracted using a 'controlled-gradient' funnel apparatus similar to that described by Macfadyen (1961). All the available type material of *Phthiracarus* species has also been examined.

For detailed studies of the external morphology, the mites were cleared and softened by heating in a test tube of 75% lactic acid in a boiling water bath, the duration of heating being dependent on the degree of sclerotization. Each mite was then transferred to a small quantity of Berlese's fluid on a slide and dissected using two fine needles. Cavity slides containing lactic acid were used for temporary preparations of the aspis, notogaster, ventral plates and ovipositor. Permanent preparations of the legs, chelicerae and infracapitulum requiring examination under oil immersion were made on plain slides in Berlese's fluid.

For each species measurements were taken from all the available specimens. The length of the aspis was taken along the mid-dorsal line and the greatest width as the transverse distance between the antiaxial margins of the bothridia. The sensillus, interlamellar and lamellar setae were measured with the aspis mounted dorsally and the rostrals with the aspis positioned laterally. The notogaster was measured in lateral aspect and the length was taken from the anterodorsal limit of the collar to a point just ventral to seta  $h_1$ . The greatest depth of the notogaster was measured between the seta  $e_1$  and the ventral margin. Each chelicera was measured from the base of the principal segment to the end of the fixed digit. For detailed study of the leg chaetotaxy, the legs were positioned laterally.

Morphological studies were also undertaken using the scanning electron microscope – good results being obtained using air-dried spirit-preserved material. Any foreign matter adhering to the specimens was first removed by brief treatment in an ultrasonic bath. The mites were then soaked in a small quantity of an anti-static solution of 0.5% 'Duron' in isobutyl alcohol for a period of 12–24 h (Sikorski *et al.*, 1967). It was found that this treatment eliminated any 'charging' due to incomplete coating of cavities such as the bothridia. After soaking, the specimens were removed from the solution, washed in isobutyl alcohol and allowed to dry. The mites were stuck onto specimen stubs using double-sided adhesive tape and coated with a 20 nm layer of evaporated gold.

## External morphology

The following account of the external morphology of *Phthiracarus* refers to the adult only; full descriptions of the immature stages will form the basis of another paper. The setal nomenclature used in the later works of Grandjean has been followed throughout the account.

### Idiosoma

**ASPIS**; Fig. 1B–D; Pl. 1a, e): A pair of oval weakly-sclerotized areas anterodorsally marks the positions of the retracted chelicerae. The ventral margin of the aspis is reflexed to form the *aspal rim* (*a.r.*) and there is a distinct *lateral ridge* (*l.r.*). The *bothridium* (*b.*) has an inner multi-chambered wall and a smooth outer one from which three finger-like chitinous *tracheoles* arise and are directed mid-dorsally. The margin of the bothridial aperture is thickened (as shown by the arrow in Pl. 1e) and flanked posteriorly by a pronounced scale. There are three pairs of procumbent dorsal setae, the *rostrals* (*ro*), *lamellars* (*la*) and *interlamellars* (*il*), and two pairs of setae laterally, the *exobothridials* (*ex*) and the *sensilli*. In most of the species examined, setae *il* and *la* are located at the level of the bothridia, *la* being somewhat shorter than *il*. The sensilli are variable in form and so provide a useful taxonomic feature. In some species they are short, ovate or lanceolate while in others they are long, narrow and tapering. The sensillar margin may be serrated (Pl. 1a) and in *P. serrulatus* sp. nov. it bears a number of straight-edged teeth subterminally. The sensillus is most easily observed in scanning electron micrographs as in flattened slide preparations its appearance can depend very much on orientation.

**NOTOGASTER** (Fig. 1A, E; Pl. 1e): The anterior margin of the notogaster is well sclerotized and, following Jacot (1930), can be subdivided into three regions: the thickened *collar* (*C*), the *pseudostigmatic* [sensillar] *notch* (*N*) (Pl. 1e) and the *lappet* (*L*) which projects somewhat anteriorly. Of the 15 pairs of setae, 14 are regarded as being homologues of  $c_{1-3}$  and  $cp$ ,  $d_{1-2}$ ,  $e_{1-2}$ ,  $h_{1-3}$  and  $ps_{1-3}$  of the holotrich nomenclature, and the additional seta as  $ps_4$ . The distributional pattern of notogastral setae is essentially similar in all the British species but the relative lengths and attitudes of the setae vary considerably from one species to another. The vestiges of setae ( $f_1$ ) and ( $f_2$ ) are thought to be represented by two pairs of subcuticular structures located posterolaterally (Grandjean, 1950). Vestigial  $f_1$  normally lies between setae  $h_1$  and  $ps_1$  and  $f_2$  between setae  $h_1$  and  $h_2$  but in certain small species (for example, *P. serrulatus*)  $f_1$  is closely associated with the seta  $h_1$ . There are four pairs of prominent subcuticular fissures: the *anterior*s (*ia*) and *median*s (*im*) are situated just posterior to seta  $cp$  while the *posterior pleural*s (*ip*) and *infrapleural*s (*ips*) (when present) are situated on either side between setae  $h_2$  and  $h_3$  and between setae  $ps_3$  and  $ps_4$  respectively.

**ANO-GENITAL REGION** (Figs 2E; 3B; Pl. 1b): On each *anal plate* there are five setae. Two *anal setae*  $an_{1-2}$  are located on the paraxial margin and three *adanals*  $ad_{1-3}$  submarginally; setae  $ad_{1-2}$  are often vestigial. Each anal plate has a prominent hood-like lobe located ventro-anteriorly on its paraxial margin and in the so-called 'left fitting' arrangement (van der Hammen, 1963) the lobe on the right-hand plate overlaps that on the left-hand plate while in the 'right fitting' arrangement (as shown by the arrow in Fig. 2E) the reverse is true. Van der Hammen has suggested that the arrangement of these interlocking lobes and the condition of setae  $ad_{1-2}$  (present or vestigial) could be useful taxonomic features. This view is not, however, supported by the present study since these two features have been found to exhibit considerable intraspecific variation.

On each *genital plate* there are two well-developed anterior ridges separated by a median furrow. The furrow bears a single *aggenital seta*  $ag_1$  antiaxially (Pl. 1b). There are nine *genital setae* arranged in two rows. The anterior five setae  $g_{1-5}$  are minute and located on the paraxial border while the posterior four setae  $g_{6-9}$  are moderately short and submarginal. There are three pairs of *genital papillae* (*g.p.*), the anterior pair being rather small. Elongate oval structures have been observed inside the genital papillae and these may prove to be spermatophores. The first two pairs of genital papillae border the *ovipositor*, which, when fully extended, can be seen to be a rather short tube divided into a distal and a proximal portion by a weak circular constriction.

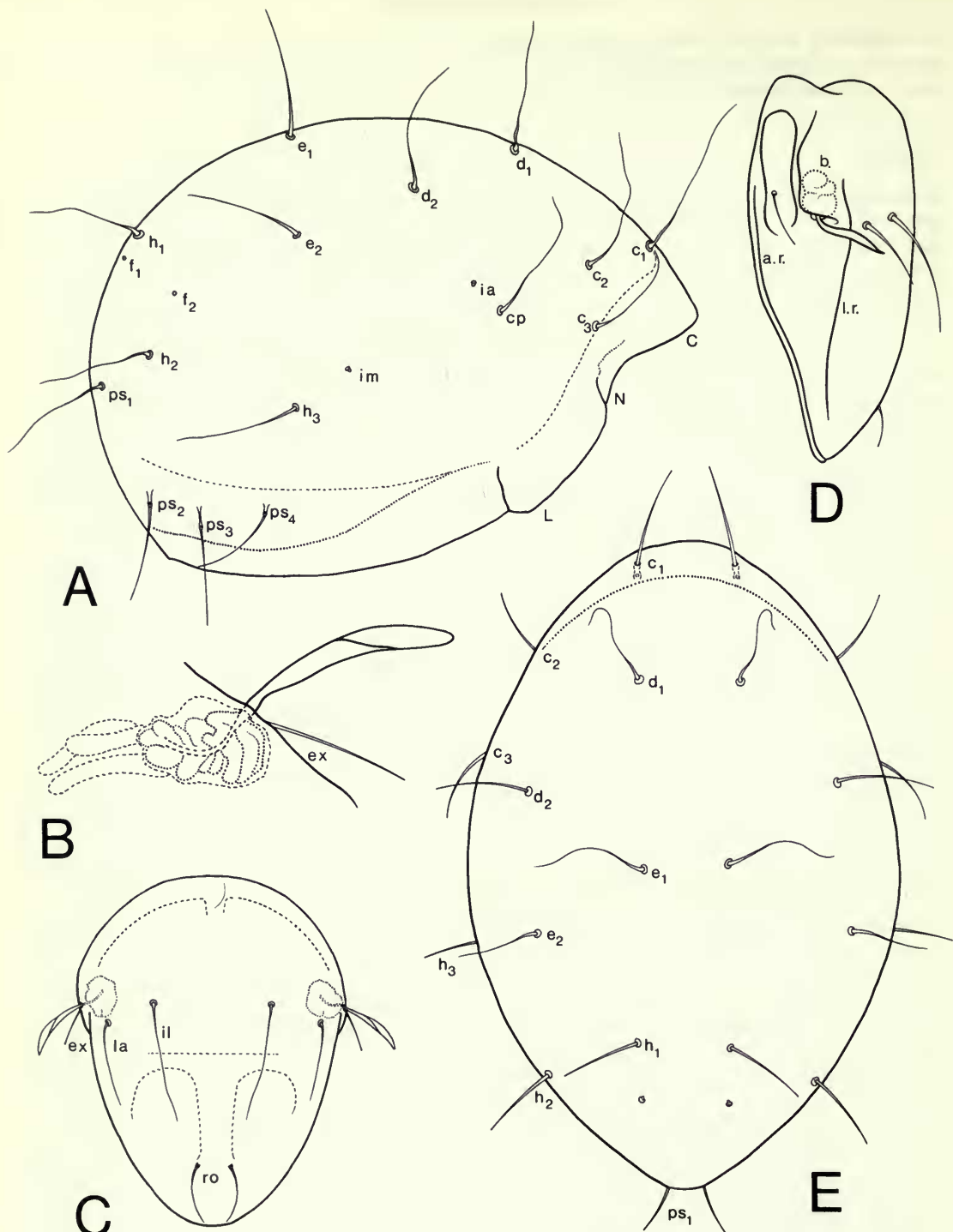
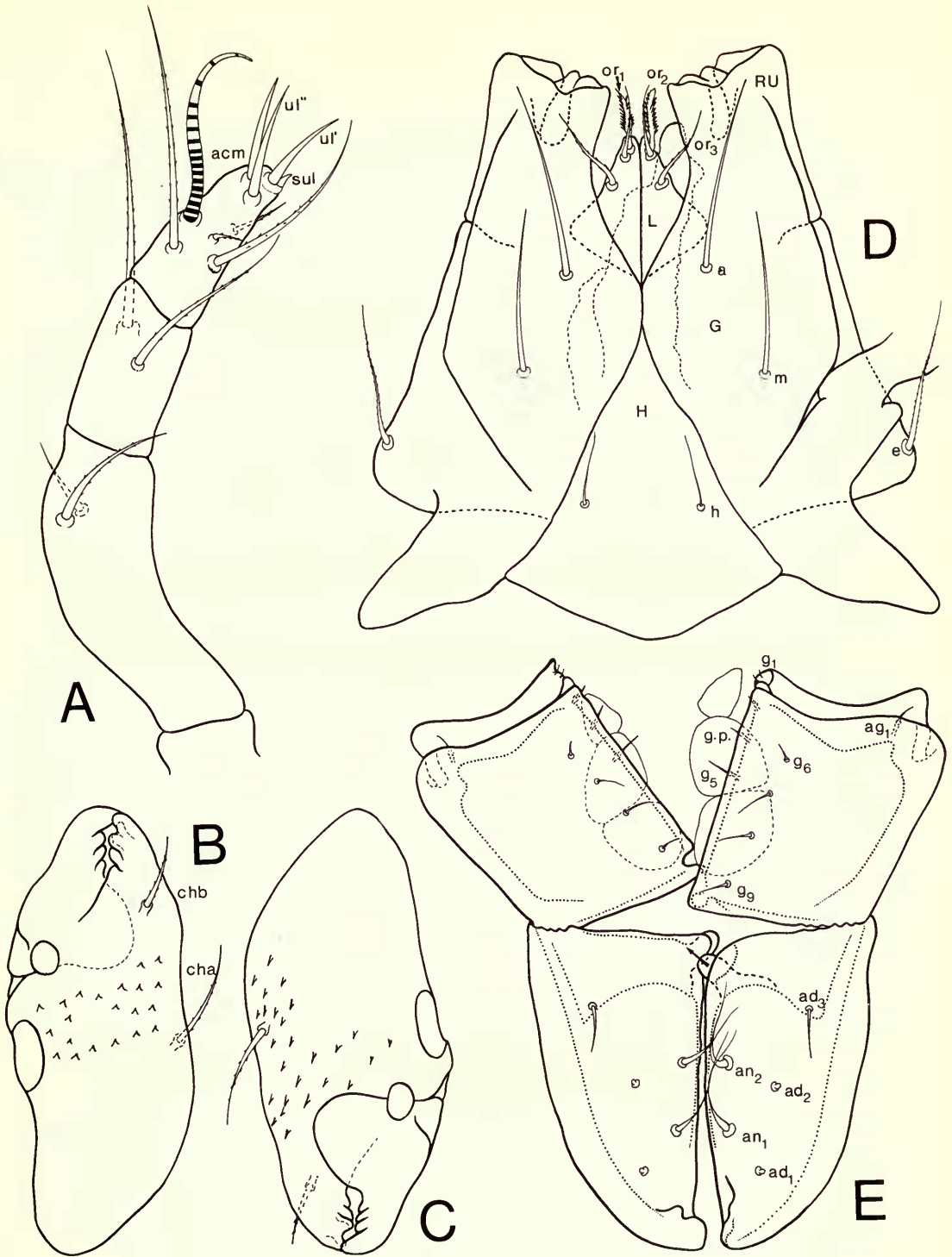


Fig. 1 *Phthiracarus affinis*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal; (D) aspis, lateral; (E) notogaster, dorsal.





**Fig. 2** *Phthiracarus affinis*: (A) pedipalp; (B) chelicera, antiaxial; (C) chelicera, paraxial; (D) infracapitulum, ventral; (E) ano-genital region.

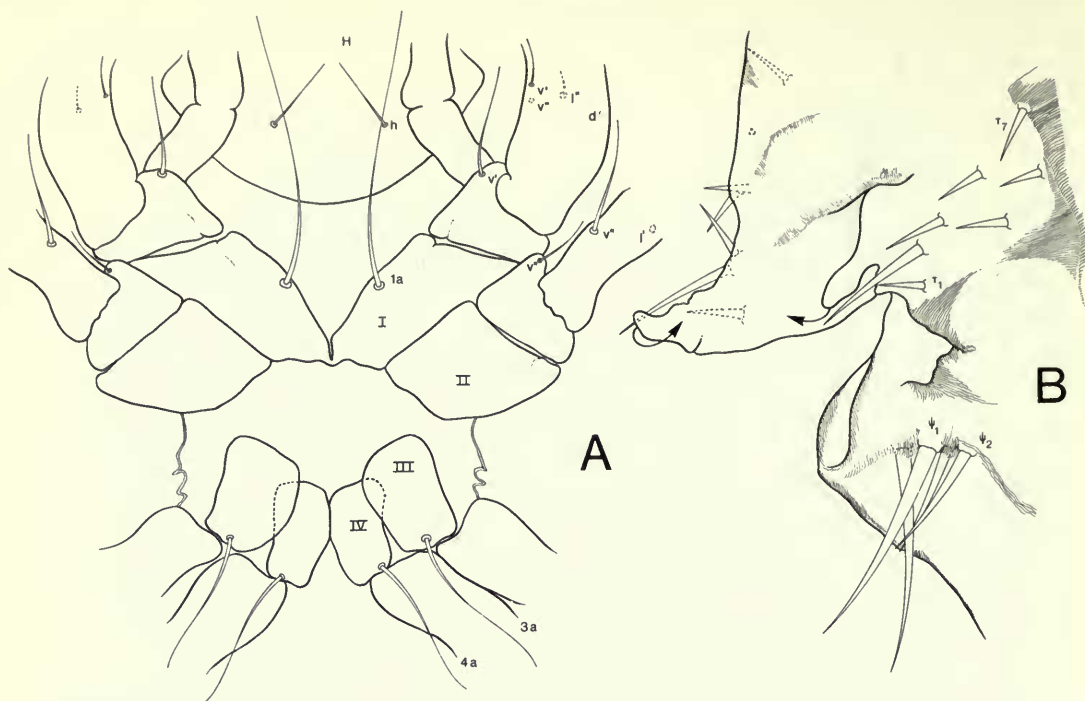


Fig. 3 *Phthiracarus affinis*: (A) coxisternal region; (B) ovipositor, lateral.

The six *coronal* (*k*) setae which Grandjean (1956) found on the constriction in *Heminothrus targionii* (Berlese) and in the 'higher' oribatid mite *Eremaeus hepaticus* C. L. Koch are apparently absent in all the British *Phthiracarus* species. The surfaces of both portions of the ovipositor are strongly pleated. Distally, three eugenital lobes surround the opening of the ovipositor: an unpaired ventral lobe and a pair of laterodorsal lobes (as shown by the arrows in Fig. 3B). The ventral lobe is triangular in anterior view and bears two pairs of setae distally ( $\psi_{1-2}$ ), the posterior pair ( $\psi_2$ ) being the shorter. The two laterodorsal lobes are larger, compressed laterally, and each bears seven setae ( $\tau_{1-7}$ ) antiaxially.

Feider & Suci (1957) figured two pairs of setae, presumably ( $\psi_1$ ) and ( $\psi_2$ ), on the ovipositor of *P. lentulus* (C. L. Koch), and in *P. parabotrichus* Feider & Suci, a dorsal group of seven setae and a smaller ventral group of three setae were shown, possibly ( $\tau$ ) and ( $\psi$ ) respectively. Harding (1976), in his description of *P. murphyi*, identified 16 setae on the ovipositor: three setae on each of the laterodorsal lobes, two setae on the ventral lobe and six setae which he considered as the coronals.

### Gnathosoma

**INFRACAPITULUM** (Fig. 2D; Pl. 1c): The *lateral lips* (*L*) bear three pairs of *adoral setae* ( $or_{1-3}$ ), the anterior pair ( $or_1$ ) being brush-like (Pl. 1c) and the two posterior pairs weakly serrated. The infracapitulum is 'sternarthrous' (Grandjean, 1957) and the *rutella* (*RU*) are without atelobasic expansions. There are three pairs of *infracapitular setae*: an *anterior* (*a*) and a *median* pair (*m*) of long smooth setae located on the *genae* (*G*) and a rather short posterior pair (*h*) located on the *hysterosoma* (*H*). Laterally there is a single pair of barbed *supracoxal setae* (*e*).

**PEDIPALPS** (Fig. 2A; Pl. 1d): The pedipalps are only three-segmented. The basal segment, formed from the fused trochanter, femur and genu, bears two setae, the tibia two setae and the tarsus seven setae and a solenidion. The three most distal of the tarsal setae are eupathidial: the

*anteroculminal acm*, *anterior ultimal ul'* and *posterior ultimal ul''*. The *subulimal seta sul* is a minute spine-like process at the base of seta *ul'* (as shown by the arrow in Pl. 1d) and also appears to be eupathidial.

**CHLICERAE** (Fig. 2B, C): Both the fixed and the movable digits are dentate. The movable digit has four teeth and the fixed digit carries five. The latter are arranged in two rows, an outer one of two and an inner one of three teeth. The large principal segment which terminates in the fixed digit, bears a number of short conical spines on the antiaxial surface and a larger number of sharply pointed spines paraxially; the spines are distributed extensively on the paraxial surface but are restricted to a more compact zone antiaxially. There are two *cheliceral setae*, an *anterior seta chb* inserted on the antiaxial surface and a *posterior seta cha* located dorsally. Both setae are serrated, *cha* being somewhat longer than *chb*.

## Legs

Legs II to IV are approximately equal in length while leg I is longer and more robust. The individual epimera are separate and, except for epimera II, each bears a single seta, *1a*, *3a* and *4a* respectively (Fig. 3A). All the legs have five segments: the trochanter, femur, genu, tibia and tarsus, and terminate in a single claw bearing two ventral teeth and an antero- and posterolateral row of serrations (Pl. 2c).

**SOLENIIDIA** (Pl. 2a, b, e): The solenidiotaxy (I 2-1-3; II 1-1-2; III 1-1-0 and IV 0-1-0) is constant in the 13 species examined and typical of that found in other Phthiracaridae. All the

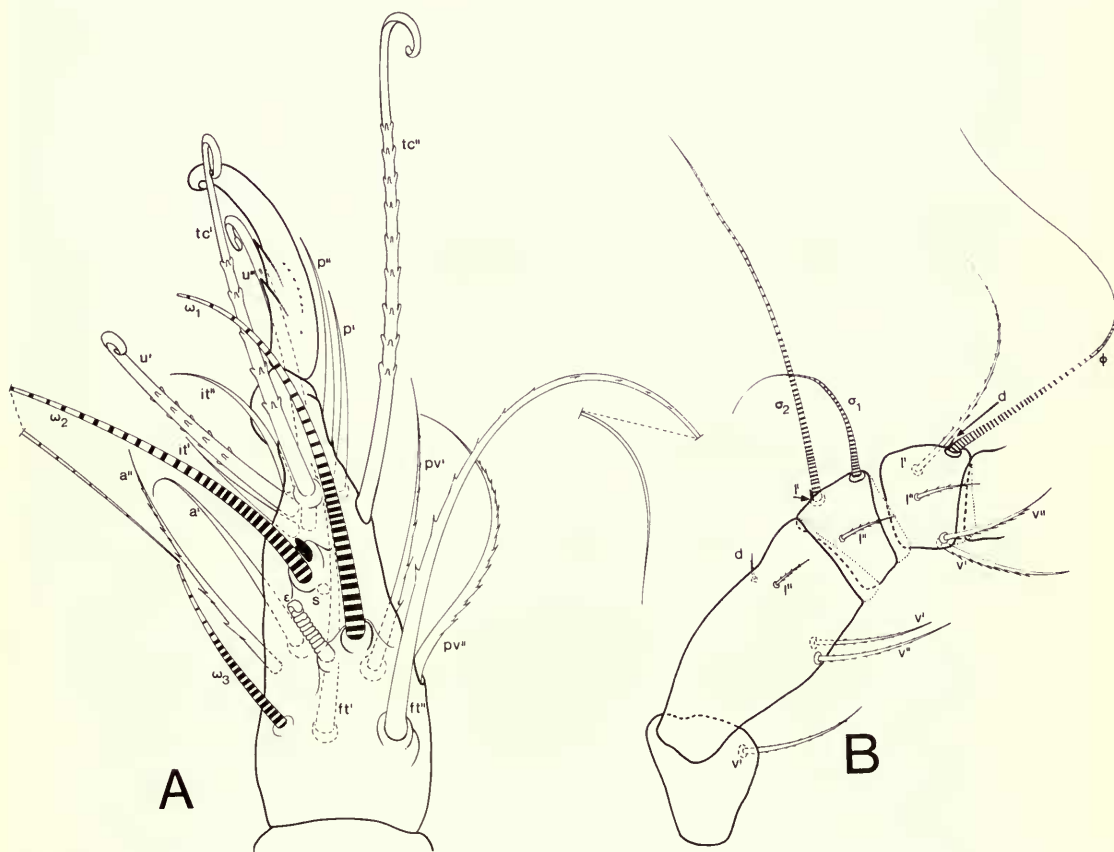


Fig. 4 *Phthiracarus affinis*, leg I: (A) tarsus, dorsal aspect; (B) trochanter to tibia, posterolateral aspect.

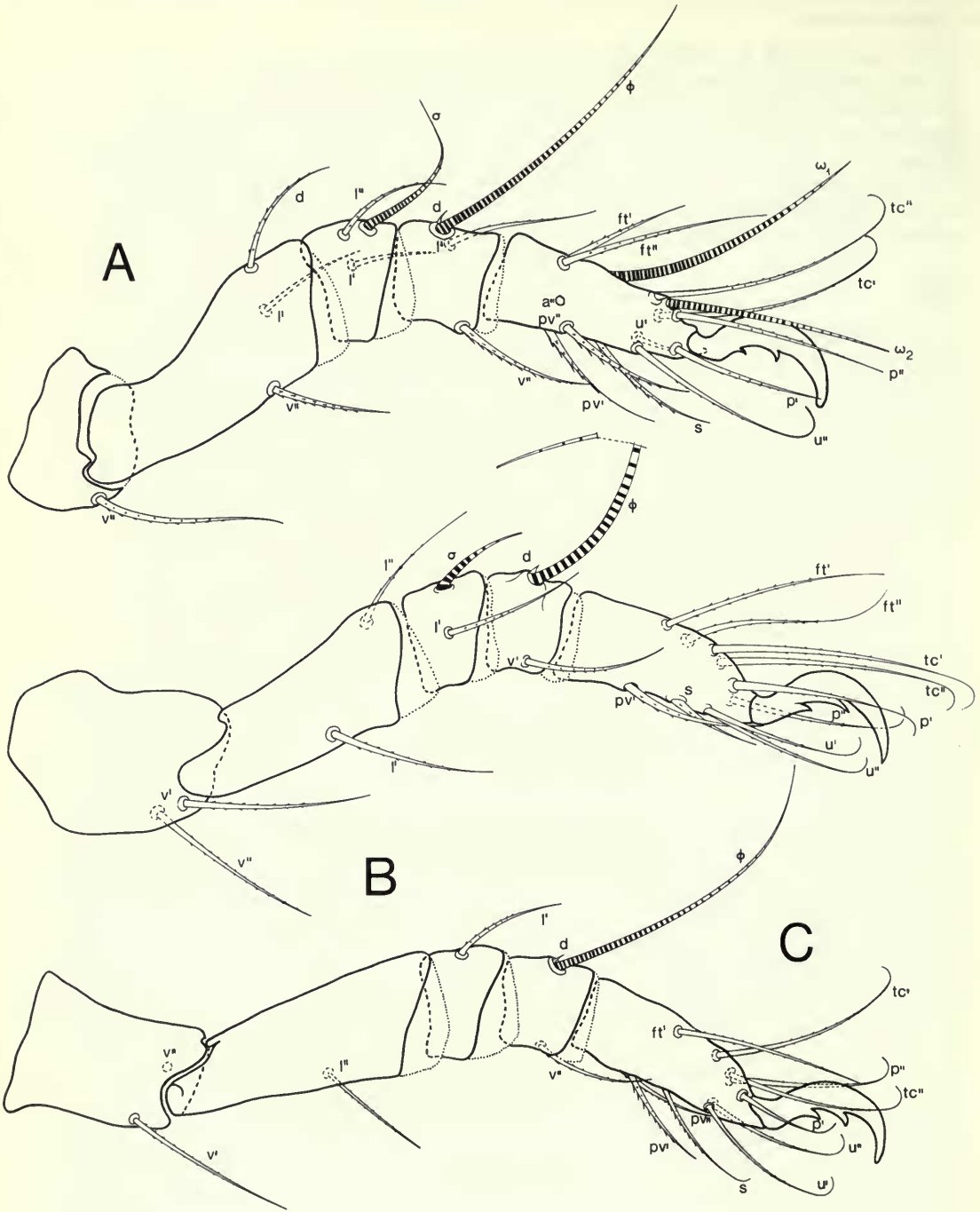


Fig. 5 *Phthiracarus affinis*, legs II–IV; (A) leg II, posterolateral aspect; (B) leg III, anterolateral aspect; (C) leg IV, anterolateral aspect. (Fig. 5A–C are drawn at the same magnification.)



tarsal solenidia are transversely striated as described by Grandjean (1935) for *Oribotritia berlesei* (Michael). On tarsus I the solenidion  $\omega_1$  is closely associated with the famulus  $\epsilon$  (Pl. 2a) which is short and rugose. Solenidion  $\omega_2$  is the longest of the three tarsal solenidia and has a small distal coupling seta (Pl. 2b). Harding (1976) described such a setal/solenidial association in *P. murphyi* and in *P. nitens* but noted that solenidion  $\omega_2$  was apparently free in *P. anonymum*. In the present study the scanning electron microscope has revealed the presence of a distal coupling seta in all the British species. Although usually short and simple, in *P. rectisetosus* sp. nov. this seta is long, prominent and apparently divided into two parts by a longitudinal constriction, the distal part being produced into a scabre-shaped process reminiscent of that found in species of the genus *Steganacarus* (see Parry, 1978). On all legs the tibial solenidion  $\phi$  is coupled with a reduced dorsal seta (Pl. 2e) while on genu I solenidion  $\sigma_2$  is coupled with a reduced lateral seta.

**LEG SETAE** (Figs 4; 5; 14; Pl. 2d): In all the larger species examined the formulae for the leg setae are: I (1-4-2-5-16-1); II (1-3-2-3-12-1); III (2-2-1-2-10-1) and IV (2-1-1-2-10-1). This complement will be referred to as the 'complete chaetotaxy type' (Figs 4; 5). On tarsus I only 16 of the 20 setae regarded by Grandjean (1940) as being characteristic of 'higher' Oribatei are present, the *primilaterals* and *postlarvals* always being absent. Four setae surround the base of the claw, namely, a dorsal pair of *prorals* (*p*) and a ventral pair of *unguinials* (*u*). Three pairs of setae are located posterodorsally to the prorals: the *iterals* (*it*), *tectals* (*tc*) and *fastigials* (*ft*). Ventrally, behind the unguinials, there is an unpaired *subunguinal* seta *s* and a pair of *primiventral* setae (*pv*). A single pair of *anterolateral* setae (*a*) is located laterally behind the prorals and the unguinials.

On tarsi II to IV there is a reduction in the number of setae to 12, 10 and 10 respectively: setae (*it*), *a'* and  $\epsilon$  are absent on tarsi II to IV, seta *pv''* on tarsus III, seta *a''* on tarsi III and IV and seta *ft''* on tarsus IV. Furthermore, the tarsal setae exhibit considerable variety in form. On tarsus I six of the setae (*s*, (*it*), (*p*) and *a'*) are hollow eupathidia. On all four tarsi setae (*ft*) and (*pv*), together with *a''* on tarsi I and II, are generally more or less straight, circular in section and bear two or three rows of lateral serrations. In certain species (for example, *P. globus* sp. nov.) seta *ft''* on tarsus II is hooked distally. The other tarsal setae, (*tc*) and (*u*) on tarsus I and (*tc*), (*u*), (*p*) and *s* on tarsi II to IV, are ribbon-like, hooked distally and covered with whorls of spicules in the middle third. Such setal ornamentation is, however, only discernible in the larger species of the genus.

The setation of the four proximal leg segments is shown in Table 1. Apart from tibia I which bears a whorl of five setae (*d*, *l'*, *l''*, *v'* and *v''*), each of the other segments bears an incomplete whorl of one to four setae. Seta *d* on femur I is somewhat thickened, serrated and curved distally (Pl. 2d) in all the species examined except *P. clavatus* sp. nov. and *P. globus* sp. nov. where it is rather long, straight and only weakly serrated. On all segments setae (*l*) and (*v*) carry two or three rows of serrations.

**Table 1** Chaetotaxy of the four proximal leg segments in *Phthiracarus*

Segment	Leg I	II	III	IV
Tibia	d, l', l'', v', v''	d, l', v''	d, v'	d, v''
Genu	l', l''	l', l''	l'	l'
Femur	d, l'', v', v''	d, l', v''	l', l''	l''
Trochanter	v'	v''	v', v''	v', v''

In all the smaller species of the genus (for example, *P. tardus* Forsslund) there are fewer setae on legs I, II and IV (Fig. 14): tarsus I bears 15 setae (*a'* absent), tarsi II and IV usually bear 11 and 9 setae respectively (*s* absent), femur I bears 3 setae (*v'* absent) and genu IV is without any setae (*l'* absent). Thus the setal formulae (referred to here as the 'reduced chaetotaxy type') are: I (1-3-2-5-15-1); II (1-3-2-3-11-1); III (2-2-1-2-10-1) and IV (2-1-0-2-9-1). In *P. anonymum* (a variant of the 'reduced chaetotaxy type') the number of setae on tarsus IV is further reduced

by the absence of seta *pv'*. Although the total number of setae on leg III is constant throughout the genus, in species of the 'complete chaetotaxy group' seta *pv''* is absent and seta *s* present while the reverse is true in the 'reduced' group.

## Review

Perty proposed the genus *Phthiracarus* in 1839 and two years later created the 'family' Phthiracarea (now Phthiracaridae) for the single species *P. contractilis*. Perty's original specimens are presumed to be lost and his figures (subsequently published by Claparède, 1868) and description are such as to make the specific identity of *contractilis* impossible to determine.

*Acarus piger* Scopoli, 1763, the oldest species currently classified in *Phthiracarus*, was originally assigned to the genus by Oudemans (1915). The mite described by Scopoli, for which there is no type material available, is undoubtedly ptychoid but there is no evidence to suggest that it is a species of *Phthiracarus* – it is probably a member of the Euphthiracaroida (see Jacot, 1930).

The systematic position of *Oribates dasypus* Dugès, 1834 is also somewhat uncertain although the species is evidently ptychoid. Michael (1888) recorded *dasypus* in the British Isles. The specimen labelled *Hoplophora\* dasypus* from Theydon Bois in the Michael Collection (deposited in the BMNH) is *P. clavatus*.

In 1841 ten species of *Hoplophora*, nine† of which are currently classified in *Phthiracarus*, were described by Koch from woodland habitats near Regensburg. While it seems probable that these mites have been correctly assigned to *Phthiracarus* (with the exception of *H. testudinea* which is possibly a member of the Euphthiracaroida), only two of Koch's descriptions refer to 'key characters' which might permit certain reidentification. In comparison with the other Regensburg species, *H. globosa* is very 'globular' while in *H. laevigata* the notogaster is 'angled' at the level of seta *c*<sub>1</sub>. The remaining six species can only be divided into two groups on the basis of their notogastral setae; *crinita*, *ferruginea* and *longula* are each characterized by 'long setae' while the other three species (*lentula*, *lucida* and *straminea*) are all described as being 'sparsely setose'. Despite the inadequacy of Koch's descriptions and the apparent absence of any type material, various interpretations of his species have been published, amongst others by Jacot and van der Hammen. In *Les Phthiracaridae de Karl Ludwig Koch*, Jacot (1936) redescribed six species from topotypic material but neglected details of the leg and notogastral chaetotaxy, now regarded as being essential for the separation of *Phthiracarus* species. More recently, van der Hammen (1963), in one of his series of papers on the Phthiracaridae, has published a detailed description of *P. laevigatus* (from material collected at Regensburg) and has designated a neotype. Van der Hammen (personal communication) also believes that he has topotypic material of Koch's seven other species but until these specimens have been examined it seems advisable to postpone any decision concerning their taxonomic status.

*Hoplophora nitens* Nicolet (1855), recorded as common in the woods around Paris, is a *Phthiracarus* species. The true identity of *nitens* appears to be doubtful, although van der Hammen's redescription (see Hammen, 1964) from topotypic material is generally accepted.

*Hoplodermia italicum* Oudemans (1907), recorded from Tiarno, Italy, is not based on a type specimen but on Berlese's description of *H. dasypus* which Oudemans regarded as being distinct from *O. dasypus* Dugès. Van der Hammen (1952) considers the specimens of both Berlese and Oudemans as being useless for reidentification purposes.

\* Certain species now assigned to *Phthiracarus* have in the past been classified in two other genera, *Hoplophora* C. L. Koch and *Hoplodermia* Michael. The genus *Hoplophora* was erected by Koch in 1836 for two species, *H. decumana* C. L. Koch and *H. stricula* C. L. Koch, currently classified in *Oribotritia* and *Steganacarus* respectively. In 1841 Koch described further species of *Hoplophora* but did not publish a diagnosis of the genus or designate a type (*H. laevigata*) until the following year. Jacot's 1928 application to the International Commission on Zoological Nomenclature for a ruling on the validity of the type designation (Koch, 1842) for a genus first published six years earlier (Koch, 1836) was not published until 1946 (see Jacot, 1946). The Commission's subsequent ruling (I.C.Z.N., 1953) allowed *H. laevigata* to be retained as the type (*H. laevigata* is here regarded as a species of *Phthiracarus*) since the genus was not originally monotypic and did not contain a species called *typus* or *typicus*. However, the generic name *Hoplophora* had been found by Michael (1898) to be preoccupied by *Hoplophora* Perty, 1833 (Neuroptera), and the new name *Hoplodermia* was proposed.

† The tenth species of *Hoplophora*, *H. ardua*, is now classified in *Rhysotritia*.

*Hoplodermis boreale* Trägårdh (1910) and *Hoplodermis affine* Hull (1914) are both *Phthiracarus* species. This is evident from the figures of these mites and has been confirmed by examination of 'cotype' and syntype material respectively. The characteristic features of these two species are now certain.

Oudemans (1915) proposed the name *Phthiracarus undatus* for the 'larve' of *Hoplophora stricula* (*sensu* Nicolet, 1855). While Nicolet's figures and description appear to refer to an adult oribatid mite, there is no evidence to suggest a *Phthiracarus* species.

Berlese (1920 & 1923) described six species of *Phthiracarus*: *rotundus*, *roubali* and *subglobosus* are European while *P. nigerrimus* was collected from Argentina, *P. curtulus* from the United States and *P. pudicus* from South Africa. The type of each of these species has been examined by Dr J. G. Sheals (BMNH) who has found that their condition is such as to make any chaetotactic characters impossible to discern. In 1959 van der Hammen reviewed all Berlese's species of primitive oribatid mites deposited in the 'Stazione di Entomologia Agraria', Florence, but could not confirm the identities of any of the *Phthiracarus* species.

Jacot (1928–1939) described 13 species from North America and a single species (*P. insularis*) from the Marquesas Islands. Of these, type material is available for eight species (see Appendix 1), seven of which are represented by a number of 'cotypes' while only *P. brevisetae* is based on a holotype. All Jacot's *Phthiracarus* specimens are mounted in Canada Balsam, the majority being entire and uncleaned. The shape of the sensillus and the relative lengths and attitudes of the dorsal notogastral setae can usually be seen in such preparations but the leg chaetotaxy is extremely difficult to study. In view of the condition of Jacot's material, it seems advisable to postpone any decision regarding the identities of his *Phthiracarus* species until all the type specimens have been dismantled and cleared (an exercise which will be complicated by the presence on each 'cotype' slide of additional species of this and other genera). It can, however, be noted that *P. brevisetae* appears to be close to if not conspecific with *P. laevigatus*, while the differences between *anonymus amicus* and Grandjean's *anonymum* are evidently not sufficient to warrant subspecific ranking. *P. insularis* and *P. setosellum bryobium* possibly have affinities with two British species, *P. murphyi* and *P. clavatus* respectively.

In 1933 Grandjean published the first of a series of detailed works on the external morphology of *P. anonymum*, a species he recorded from rotting wood in his cellar at Périgueux, Dordogne, France. By clearing whole and dissected specimens (Grandjean, 1949) he was able to observe the patterns of setae on the body shields (Grandjean, 1933, 1934 & 1950), which provided new criteria for the identification of species of this genus. Hitherto, species differentiation had been based almost entirely on body shape and colour, two characters now known to be uniform in many *Phthiracarus* species. Grandjean (1935, 1940 & 1946) also undertook the first detailed studies of the leg chaetotaxy of oribatid mites, introducing the system of nomenclature now in general use. However, in recent years the majority of *Phthiracarus* species have been defined solely in terms of characters visible in undissected material. Leg chaetotactic characters have only rarely been studied (van der Hammen, 1963; Sheals, 1965; Ramsay, 1966; Harding, 1976) probably due to difficulties in interpretation.

Further *Phthiracarus* species have been described by Willmann (1932, 1939 & 1951), Woolley (1954) and Forsslund (1956) (see under Descriptions of species). However, *P. peristomaticus*, recorded by Willmann (1951), from a number of habitats including leaves, turf and subsoil under buckthorn, guelder-rose and alder, nördlich Moosmühle, near Vienna, Austria, cannot be identified either from Willmann's figure or from his description. Moreover, there are no specimens of *P. peristomaticus* in Willmann's Collection (Dr W. Hirschmann, personal communication). Feider *et al.* (1957, 1958 & 1968) recorded eight species from Rumania, none of which were described in sufficient detail to permit certain reidentification, although *P. baloghi*, collected from oak leaves in Iași, appears to be unique among described species of the genus in having notogastral setae of two markedly different lengths. Unfortunately, it has not been possible to borrow the types of any of the Rumanian species for study. This was also the case with species described by Balogh (1958, 1962, 1963 & 1977) and Krivolutsky (1966 & 1975). Other *Phthiracarus* species have been described from Japan (Aoki, 1958 & 1963), Chile (Hammer, 1962), Nepal (Sheals, 1965), New Zealand (Ramsay, 1966), Spain (Pérez-Iñigo, 1969), Tahiti (Hammer, 1972), the



Tonga Islands (Hammer, 1973) and the British Isles (Harding, 1976) (see Appendix 1). Of these, *P. robertsi*, recorded by Sheals from rhododendron litter in Nepal, is of particular interest for, although having certain affinities with *Phthiracarus*, it shows a general similarity to *Steganacarus*. The arrangement of setae on the genital and anal plates, while reminiscent of *Phthiracarus*, is nevertheless 'unusual' for setae  $ad_{1-3}$  are almost marginal. The only diagnostic feature which *P. robertsi* appears to share with all species of the genus is the presence of a coupled solenidion on tibia IV. The general shape of the aspis and the form of the integumental ornamentation are characteristic of *Steganacarus* species and it is questionable whether *P. robertsi* should have been classified in *Phthiracarus* (see Sheals, 1969).

There have been relatively few reviews of the British species. In his *Synonymic catalogue of British Acari*, Turk (1953) listed only five species of *Phthiracarus*: *piger* (Scopoli) (= *Hoplophora dasyus* Dugès *sensu* Michael), *affine* (Hull), *anonymum* Grandjean, *ligneus* Willmann and *spinosum* (Sellnick) (now classified in *Steganacarus*). Turk does not give sources for individual records but the above are presumably based on the following published records: Michael, 1888, Halbert, 1915 and Hull, 1916 (*dasyus*); Hull, 1914 (*affine*); Murphy, 1954 (*anonymum*); Macfadyen, 1952 (*ligneus* and *spinosum*). Of these, only *P. affinis* and *anonymum* are recognized in the present revision since the taxonomic status of the other two *Phthiracarus* species is doubtful.

## Descriptions of species

### Genus *PHTHIRACARUS* Perty

*Hoplophora* Koch, 1836 : Hft. 2, Nr. 9. Preoccupied name (Michael, 1898 : 77). Type, by subsequent designation, *Hoplophora laevigata* Koch, 1841 : Hft. 38, Nr. 16.

*Phthiracarus* Perty, 1839 : column 847. Type, by monotypy, *Phthiracarus contractilis* Perty, 1841 : 874. Figured by Claparède, 1868 : pl. 36, figs 15–19.

*Hoploderma* Michael, 1898 : 77. Proposed as replacement name for *Hoplophora* Koch.

**DEFINITION:** Weak to heavily sclerotized Phthiracaridae ranging in length from about 350–1300 µm (lateral measurement taken in closed position). The integument of the dorsal and ventral shields, infracapitulum and chelicerae is densely punctate while that of the appendages is smooth. The interlamellar and lamellar setae are procumbent and the aspis without a median keel. The notogaster bears 15 pairs of fine and generally smooth setae. Fissures *ip* and *ips* may be present or absent. The notogaster bears neither a cowl nor a carina. Two pairs of anal setae are located on the paraxial margins of the anal plates and three pairs of adanals submarginally (the exception being *P. anonymum* with three pairs of setae located marginally). All are usually more or less equal in length although the two posterior pairs of adanal setae may be vestigial. The genital setae are arranged in a pattern of 5+4 along the paraxial margins of the genital plates. On leg IV the tibial solenidion is coupled.

**DIAGNOSIS:** *Phthiracarus* is distinguished from other genera of the Phthiracaridae by having a combination of procumbent interlamellar setae and a 2+3 arrangement of setae on the anal plates.

### Key to adults of the British species of the genus *Phthiracarus*

Only two species can be recognized on the basis of a single character. In *P. anonymum* seta  $ad_3$  is located marginally (submarginally in all other species) while *P. laevigatus* appears to differ from all the other members of this genus in that the notogaster is strongly arched at the level of seta  $c_1$ .

It has been concluded from an investigation of the external morphology of the British species that the number of setae on femur I (4 or 3) and genu IV (1 or 0), the shape of the sensillus, the presence or absence of fissures *ip* and *ips* and the relative lengths and attitudes of the notogastral setae are the most useful characters for species differentiation. These are the main characters used in the following key.

- |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 1 | Femur I with four setae (Fig. 4B); genu IV with a single seta (Fig. 5C) | . | . | . | . | 2 |
| – | Femur I with three setae (Fig. 14B); genu IV without setae              | . | . | . | . | 9 |
| 2 | Notogastral fissures <i>ip</i> and <i>ips</i> absent (Fig. 1A)          | . | . | . | . | 3 |
| – | Notogastral fissures <i>ip</i> and <i>ips</i> present (Fig. 10D)        | . | . | . | . | 6 |



- 3 Sensillus about 80  $\mu\text{m}$  long, narrow and pointed distally (Pl. 4d); notogastral setae shorter than  $c_1 - d_1$  . . . . . *P. juvenalis* sp. nov. (p. 342)
- Sensillus not of this form; notogastral setae equal to or greater than  $c_1 - d_1$  . . . . . 4
- 4 Notogastral setae procurved (Fig. 7A); sensillus as in Pl. 3f . . . . . *P. clavatus* sp. nov. (p. 338)
- Notogastral setae erect . . . . . 5
- 5 Large species, notogaster over 550  $\mu\text{m}$  in length; seta *d* on femur I straight *P. globus* sp. nov. (p. 341)
- Smaller species, notogaster under 500  $\mu\text{m}$  in length; seta *d* on femur I curved distally (Pl. 2d) *P. affinis* (Hull) (p. 335)
- 6 Notogaster sharply angled at the level of seta  $c_1$  when viewed laterally (Fig. 10D) *P. laevigatus* (C. L. Koch) (p. 344)
- Notogaster rounded anteriorly when viewed laterally (Fig. 1A). . . . . 7
- 7 Sensillus 50–60  $\mu\text{m}$  long, narrow and finely serrated (Fig. 12A); notogastral setae shorter than  $c_1 - d_1$  and procurved. . . . . *P. nitens* (Nicolet) (p. 346)
- Sensillus not of this form; notogastral setae equal to or greater than  $c_1 - d_1$  . . . . . 8
- 8 Notogastral setae procurved; on tarsus I seta coupled with solenidion  $\omega_2$  much shorter than famulus . . . . . *P. murphyi* Harding (p. 346)
- Notogastral setae almost erect; on tarsus I seta coupled with solenidion  $\omega_2$  almost as long as famulus . . . . . *P. rectisetosus* sp. nov. (p. 348)
- 9 Notogaster with vestigial  $f_1$  just dorsal to seta  $h_1$  (Fig. 6E); seta  $ad_3$  located on paraxial margin of anal plate (Pl. 3e); tarsus IV with eight setae (Fig. 6B) *P. anonymum* Grandjean (p. 336)
- Notogaster with vestigial  $f_1$  located on a level with or ventral to seta  $h_1$ ; seta  $ad_3$  located submarginally on anal plate (Fig. 2E); tarsus IV with nine setae (Fig. 14D). . . . . 10
- 10 Sensillus about 70  $\mu\text{m}$  long . . . . . 11
- Sensillus 30–40  $\mu\text{m}$  long . . . . . 12
- 11 Sensillus with membranous border (Fig. 11B). . . . . *P. membranifer* sp. nov. (p. 344)
- Sensillus serrated distally (Fig. 13B) . . . . . *P. serrulatus* sp. nov. (p. 348)
- 12 Notogastral setae equal to  $c_1 - d_1$  and erect; tarsus II with 12 setae . . . . . *P. tardus* Forsslund (p. 351)
- Notogastral setae greater than  $c_1 - d_1$  and slightly flexuose (Fig. 7F); tarsus II with 11 setae *P. flexisetosus* sp. nov. (p. 340)

### *Phthiracarus affinis* (Hull)

(Figs 1; 2; 4; 5; Pls 2a, b, d; 3a, d)

*Hoplocleroderma affine* Hull, 1914 : 287, pl. C9.

*Phthiracarus affine*: Turk, 1953 : 89.

**ADULT** (Pl. 3a): Small and moderately sclerotized. The *aspis* (Fig. 1C, D) ranges in length from 223–253  $\mu\text{m}$  with a greatest width of 162–192  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance between the bases of setae (*il*) and (*ro*). The latter do not reach the anterior limit of the *aspis*. The sensillus (Fig. 1B; Pl. 3d) is 50–60  $\mu\text{m}$  long, lanceolate and serrated. The *notogaster* (Fig. 1A, E) ranges in length from 406–487  $\mu\text{m}$  with a greatest depth of 294–345  $\mu\text{m}$ . All the setae are relatively long (equal to the distance  $c_1 - d_1$ ), fine and erect. Setae  $c_1$  and  $c_3$  are inserted on the posterior margin of the collar and seta  $c_2$  submarginally. Vestigial  $f_1$  is located a short distance posterior to seta  $h_1$ . The fissures *ip* and *ips* are absent. On each *anal plate* (Fig. 2E) there are three setae;  $an_1$  and  $an_2$  being much longer than  $ad_3$ . The *chelicerae* (Fig. 2B, C) are about 121  $\mu\text{m}$  long. The principal segment carries 14–26 sharply pointed spines on the paraxial surface and 9–21 conical spines anti-axially. The *leg chaetotaxy* (Figs 4; 5) is of the ‘complete type’ with the setal formulae: I (1–4–2–5–16–1); II (1–3–2–3–12–1); III (2–2–1–2–10–1) and IV (2–1–1–2–10–1). On tarsus I the distal seta coupled with solenidion  $\omega_2$  is short; its form can only be seen clearly in scanning electron micrographs (Pl. 2a, b). Seta *u'* on tarsi I and II is often short and thick and resembles a eupathidium. On femur I seta *d* is short, serrated and curved distally (Pl. 2d).

**DISTRIBUTION:** *P. affinis* is apparently widely distributed in forest soils with a mor humus formation. This species was recorded in the F (fermentation) and H (humus) layers under both the hardwood and coniferous tree species at each of the four study areas (see p. 324) being particularly abundant in the F layer under beech and oak where it constituted 20–30% of the eupyctimoid population. Material collected from the following localities was also examined:

Wytham Woods Estate, Berkshire, 28.x.70 (T. G. Wood); St. Agnes, Isles of Scilly, Cornwall, 5.iv.57 (K. H. Hyatt); Bramshill Forest, Hampshire, 6.xii.70 (B. W. Parry); Woodwalton Fen, Huntingdonshire, 20.v.65 (P. N. Lawrence); Keston Bog, Kent, 8.i.56 (P. N. Lawrence); Thetford Chase, Norfolk, 23.vi.71 (B. W. Parry); Springwell Forest, Co. Londonderry, 1973 (J. Longworth); as well as material labelled '*Hoplodermma affine* Hull (Ninebanks)' in the Hull Collection deposited in the BMNH.

REMARKS: Hull (1914) recorded *affinis* in moss in woods and in *Sphagnum* on moors, West Allendale, Northumberland and Gibside, Durham and later (1916) included it in his key to species of the genus *Hoplodermma*. A holotype does not appear to have been designated and no type material is known to exist. Hull's collection was found to contain one tube labelled *Hoplodermma affine*. Three of the specimens are in good condition, conspecific and the shape of their sensilli corresponds with Hull's description: 'Pseudostigmatic organs prominent, slender, fusiform, curved outward and forward, rather long, with a fine point'. Moreover, the specimens are of a similar size to that given by Hull (about 420  $\mu$ m). One of these specimens, BMNH reg. no. 1973.28 (now mounted in Berlese's fluid), is hereby designated as the *neotype*. The fourth specimen, although badly damaged, is clearly another larger species with a differently shaped sensillus. The other British material has been compared with the neotype – no morphological differences apart from size variation could be detected.

*P. affinis* appears to be close to *P. crenophilus*, a species described by Willmann (1951) from the edge of a marsh, Ebreichsdorf, Austria, and earlier identified as *P. borealis* (Trägårdh) (see Willmann, 1923, 1928 & 1931). The syntype series (10 specimens collected in Austria, Germany and Switzerland) has been examined and found to be composed of two species, only one of which resembles Willmann's figure of *crenophilus* and also the neotype of *P. affinis*. However, the notogastral setae of the latter are considerably shorter than in *P. crenophilus*.

### *Phthiracarus anonymum* Grandjean

(Fig. 6; Pl. 3b, e)

*Phthiracarus anonymum* Grandjean 1933 : 312 (ano-genital region); 1934 : 51 (aspis & notogaster); 1950 : 73 (setae  $f_1$ ,  $f_2$  and  $ps_4$ ); van der Hammen, 1965 : 376 (leg chaetotaxy).

[*Phthiracarus anonymum*: Feider & Suciu, 1957 : 24. Misidentification.]

ADULT (Pl. 3b): Small, weakly sclerotized and opalescent. The *aspis* (Fig. 6C) ranges in length from 208 – 248  $\mu$ m with a greatest width of 162 – 172  $\mu$ m. All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il-ro*. The rostrals which are inserted relatively far apart are widely removed from the anterior margin. The sensillus (Fig. 6D) is short (20  $\mu$ m), ovate and serrated. The *notogaster* (Fig. 6E) ranges in length from 406 – 466  $\mu$ m with a greatest depth of 253 – 294  $\mu$ m. All the setae are short (less than the distance  $c_1 - d_1$ ), fine and erect. Setae  $c_1$  and  $c_3$  are inserted on the posterior margin of the collar and seta  $c_2$  submarginally. Vestigial  $f_1$  is located just dorsal to seta  $h_1$ . The fissures *ip* and *ips* are absent. On each *anal plate* (Pl. 3e) there are five relatively short setae, of which, three, evidently  $ad_3$  and  $an_{1-2}$ , are inserted on the paraxial margin, the longest in the row being  $an_1$  which is approximately twice as long as  $ad_3$ . The *chelicerae* are approximately 137  $\mu$ m in length. The principal segment carries about 12 sharply pointed spines on the paraxial surface and about 10 conical spines antiaxially. The *leg chaetotaxy* is of the 'reduced type' with the setal formulae: I (1-3-2-5-15-1); II (1-3-2-3-11-1); III (2-2-1-2-10-1) and IV (2-1-0-2-8-1). On tarsus I (Fig. 6A) true setae and eupathidia are difficult to distinguish since the former are more or less straight distally. The distal seta coupled with solenidion  $\omega_2$  resembles that of *P. affinis*. Seta  $u'$  on tarsi I and II is often short and thick and resembles a eupathidium. On tarsus IV (Fig. 6B) seta  $pv'$  is absent.

DISTRIBUTION: *P. anonymum*, the only endophagous species identified in the present study, is apparently widely distributed in the F layer or mor forest soils. This species was common under both the hardwood and coniferous tree species at each of the study areas (see p. 324) being particularly abundant under oak where it constituted 5 – 10% of the euptyctimoid population.

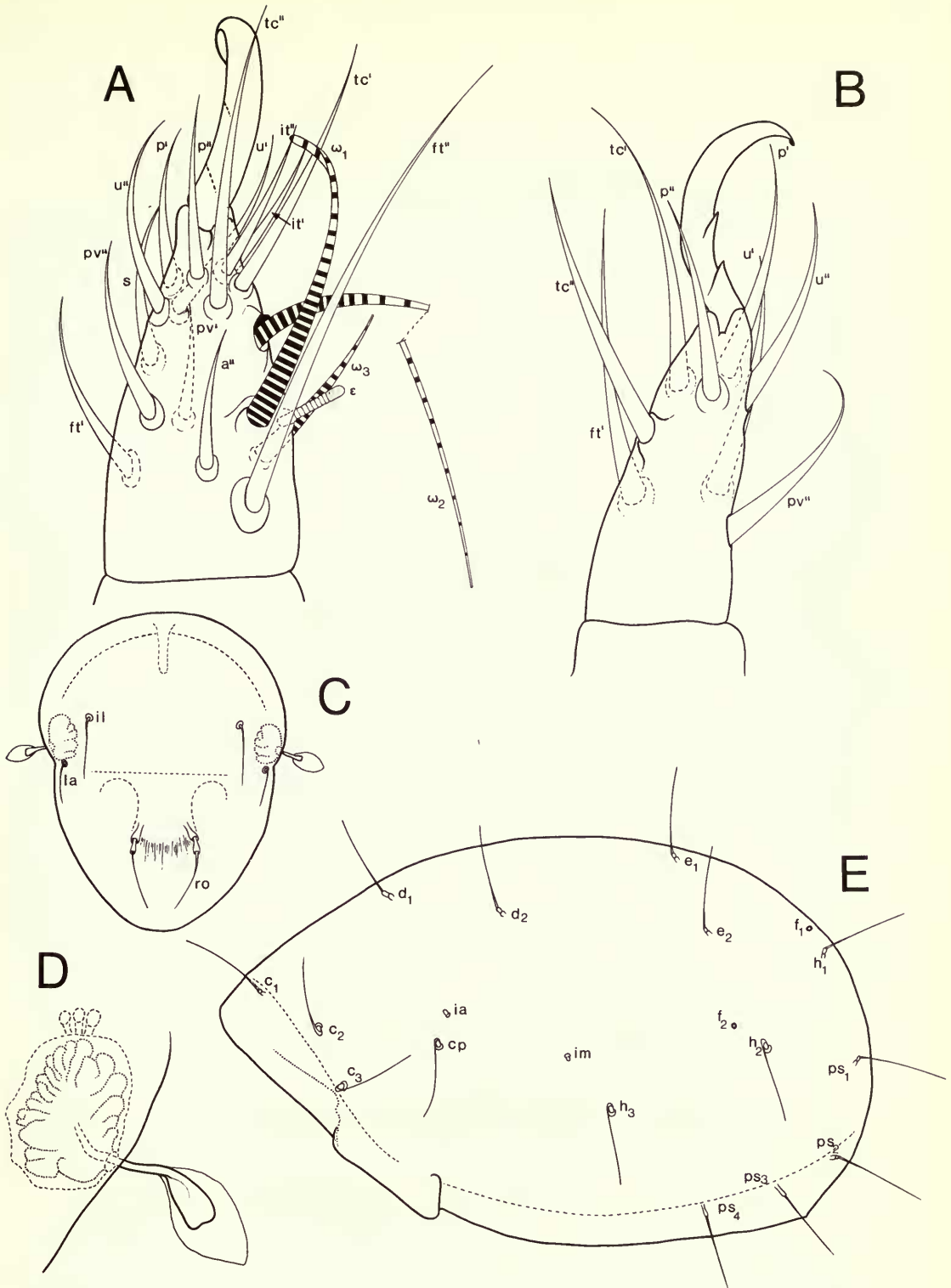


Fig. 6 *Phthiracarus anonymus*: (A) tarsus I, posterolateral aspect; (B) tarsus IV, posterolateral aspect; (C) aspis, dorsal; (D) sensillus and bothridium; (E) notogaster, lateral. (Fig. 6A, B are drawn at the same magnification.)



Material was also examined from: Wytham Woods Estate, Berkshire, 28.x.70 (T. G. Wood); Burnham Beeches, Buckinghamshire, 1964 (G. O. Evans); Bramshill Forest, Hampshire, 6.xii.70 (B. W. Parry); Woodwalton Fen, Huntingdonshire, 20.iv.65 (P. N. Lawrence); Hollows Wood, Kent, 3.iv.60 (P. N. Lawrence); Grasmere, Westmorland, 3.xii.54 (M. Bacchus); Meathop Wood, Westmorland, 19.iii.63 (P. N. Lawrence); Shawley Woods, Worcestershire, 4.x.63 (F. Flowers); Springwell Forest, Co. Londonderry, 1973 (J. Longworth); Périgueux, Dordogne, France (topotypes).

REMARKS: In comparison with the other British *Phthiracarus* species examined, *P. anonymum* is somewhat atypical: it alone is opalescent; bears  $f_1$  dorsal to  $h_1$ ; carries  $ad_3$  on the paraxial margin of the anal plate and lacks the anterior primiventral seta on tarsus IV. The British material has been compared with a number of topotypes – no morphological differences could be detected.

*P. anonymus amicus* Jacot, described from deciduous leaf mould, Connecticut Hill, New York, USA, may well prove to be conspecific with *P. anonymum*. Jacot (1938) based his description on the position of seta  $d_2$  and the length of seta  $an_1$ ;  $d_2$  was located further towards  $d_1$  than was in fact shown in Grandjean's figure (Grandjean, 1934) while seta  $an_1$  appeared to be longer. Although Grandjean's figure does indeed differ in these two respects from Jacot's *anonymus amicus*, the topotypic material of *anonymum* which has been examined agrees well with Jacot's description. A 'cotype' of *anonymus amicus* (slide no. 32108h2, undissected and mounted in Canada Balsam) has been examined and appears to be close to *anonymum* although the seta  $an_1$  is difficult to discern. Moreover, Jacot's species (diagonal length of notogaster about 400  $\mu\text{m}$ ) falls within the size range given by Grandjean (notogastral length 330 – 420  $\mu\text{m}$ ).

***Phthiracarus clavatus* sp. nov.**

(Fig. 7A–C; Pl. 3c, f)

ADULT (Pl. 3c): Large and strongly sclerotized. The *aspis* (Fig. 7C) ranges in length from 279 – 324  $\mu\text{m}$  with a greatest width of 192 – 208  $\mu\text{m}$ . All the dorsal setae are long and conspicuous. Setae (*il*) and (*la*) are more or less equal in length and both pairs of setae reach the level of the rostrals. The latter extend to the anterior margin of the aspis. In the paratype setae (*la*) are only half the length of setae (*il*). The sensillus (Fig. 7B; Pl. 3f) is 30 – 40  $\mu\text{m}$  long, broadly clavate and distinctly serrated in the distal half. The *notogaster* (Fig. 7A) ranges in length from 619 – 659  $\mu\text{m}$  with a greatest depth of 421 – 458  $\mu\text{m}$ . All the setae are long (more than the distance  $c_1 - d_1$ ) and procurved. Setae  $c_{1-3}$  form a row just behind the posterior margin of the collar. Vestigial  $f_1$  is located a short distance posterior to seta  $h_1$ . The fissures *ip* and *ips* are absent. On each *anal plate* there are five long setae;  $an_{1-2}$  and  $ad_3$  being more or less equal in length and somewhat shorter than  $ad_{1-2}$ . The *chelicerae* are approximately 182  $\mu\text{m}$  in length. The principal segment carries about 20 sharply pointed spines on the paraxial surface and about 18 conical spines antiaxially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1–4–2–5–16–1); II (1–3–2–3–12–1); III (2–2–1–2–10–1) and IV (2–1–1–2–10–1). On tarsus I the distal seta coupled with solenidium  $\omega_2$  is rather short. Seta *d* on femur I is long, straight and only weakly serrated.

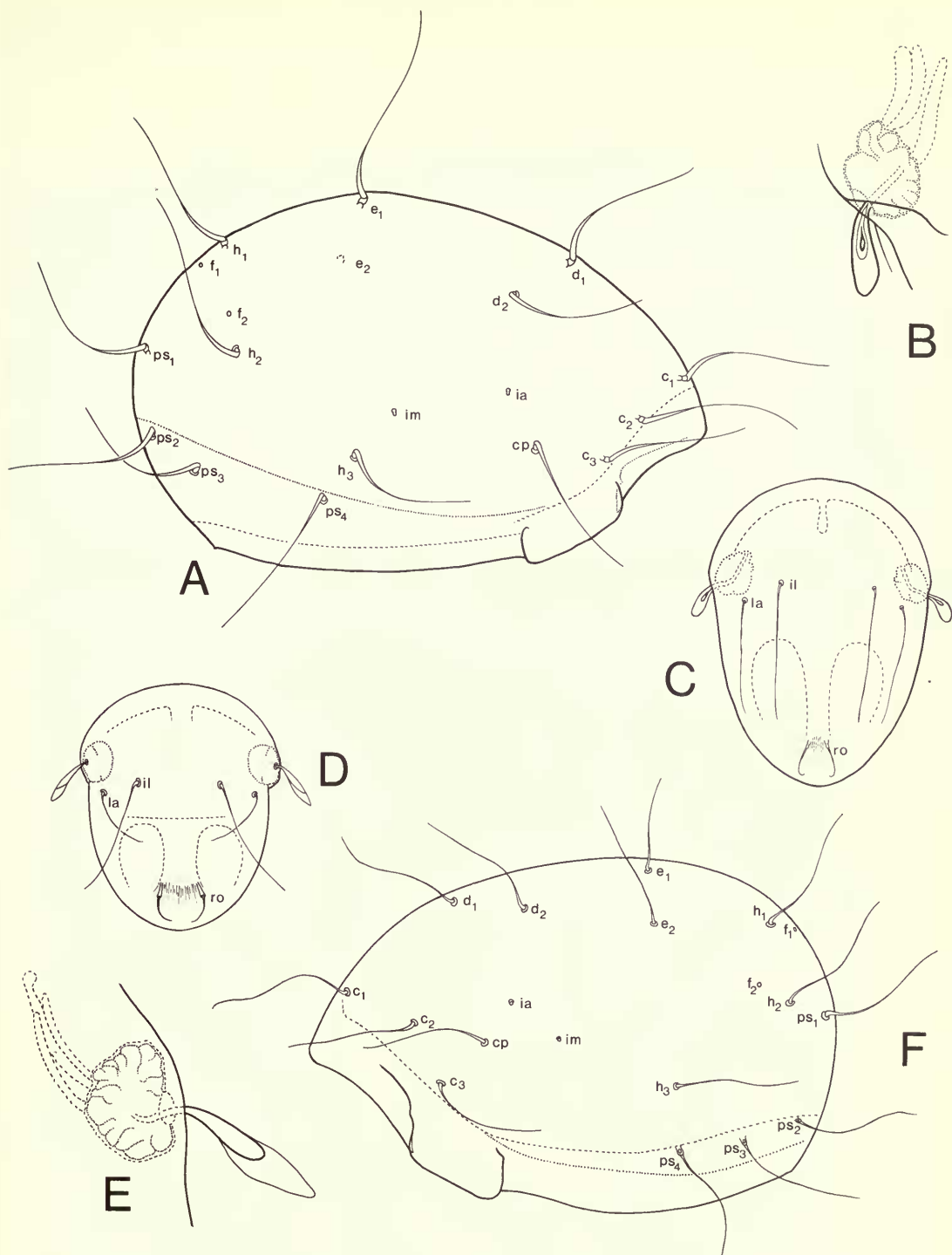
TYPES: Holotype, BMNH reg. no. 1976.2.18.1, from mull soil, Meathop Wood, Westmorland, 19.iii.63 (P. N. Lawrence). Paratype, 1976.2.18.2, from *Phragmites* litter, Woodbastwick Marshes, Norfolk, 10.vii.74 (S. J. Moore).

DISTRIBUTION: *P. clavatus* was also recorded from The Woburn Estate, Bedfordshire, 10.iv.72 (B. W. Parry) and from Rosthwaite, Cumberland, 18.v.59 (P. N. Lawrence). This species was not abundant in any of the samples examined.

REMARKS: *P. clavatus* appears to be similar to *P. borealis* (Trägårdh) recorded in rotting birch leaves, Sarek, Swedish Lapland. Three 'cotypes' of *borealis* (cleared but undissected) were examined and found to be generally larger (notogastral length 659 – 842  $\mu\text{m}$ ) and more heavily sclerotized than *clavatus*. Moreover, in *P. borealis* the notogastral setae are erect while in *P. clavatus* they are procurved. The general form of the sensillus is similar in both species.

*P. clavatus* also resembles *P. setosellum bryobium* described by Jacot (1930) from upland





**Fig. 7A–C** *Phthiracarus clavatus*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal.

**Fig. 7D–F** *Phthiracarus flexisetosus*: (D) aspis, dorsal; (E) sensillus and bothridium; (F) notogaster, lateral.

swamp moss, East Village, Monroe, Connecticut, USA. However, in comparison with *clavatus*, the 'cotype' of *setosellum bryobium* is much smaller (notogastral length about 252  $\mu\text{m}$ ). The notogastral setae appear to be of the same general form in both species. The sensillus, which appears to be lobular in Jacot's figure, is missing in the 'cotype'.

*Phthiracarus flexisetosus* sp. nov.

(Fig. 7D–F)

**ADULT:** Medium-sized and moderately strongly sclerotized. The *aspis* (Fig. 7D) ranges in length from 230–255  $\mu\text{m}$  with a greatest width of 170–220  $\mu\text{m}$ . All the dorsal setae are fine and rather long. Setae (*il*) are about 1.5 times the length of setae (*la*) and equal to the distance *il*–*ro*. The rostrals, which are inserted relatively far apart, do not reach the anterior limit of the *aspis*. The sensillus (Fig. 7E) is 30–40  $\mu\text{m}$  long, broadly clavate, serrated and closely resembles that found in *P. clavatus*. The *notogaster* (Fig. 7F), about 560  $\mu\text{m}$  long and with a greatest depth of about 330  $\mu\text{m}$ , is elongate in lateral aspect. All the setae are long (more than the distance  $c_1 - d_1$ ), fine and slightly flexuose. Setae  $c_1$  and  $c_3$  are inserted on the posterior margin of the collar and seta  $c_2$  submarginally. Vestigial  $f_1$  is located adjacent to seta  $h_1$  and towards the mid-dorsal line. The fissures *ip* and *ips* are absent. On each *anal plate* there are only three setae, of which  $ad_3$  is rather short. The *chelicerae* are about 172  $\mu\text{m}$  long. The principal segment carries 16–19 sharply pointed spines on the paraxial surface and 12–17 conical spines antiaxially. The *leg chaetotaxy* is of the 'reduced type' with the setal formulae: I (1–3–2–5–15–1); II (1–3–2–3–11–1); III (2–2–1–2–10–1) and IV (2–1–0–2–9–1). On tarsus I seta *u'* is short, thick and resembles a eupathidium.

**TYPES:** Holotype, BMNH reg. no. 1976.2.18.17, and two paratypes, 1976.2.18.18–19, from the F layer under a mixed stand of beech and oak, New Forest, Hampshire, 27.iii.73 (B. W. Parry). *P. flexisetosus* is known only from the type locality.

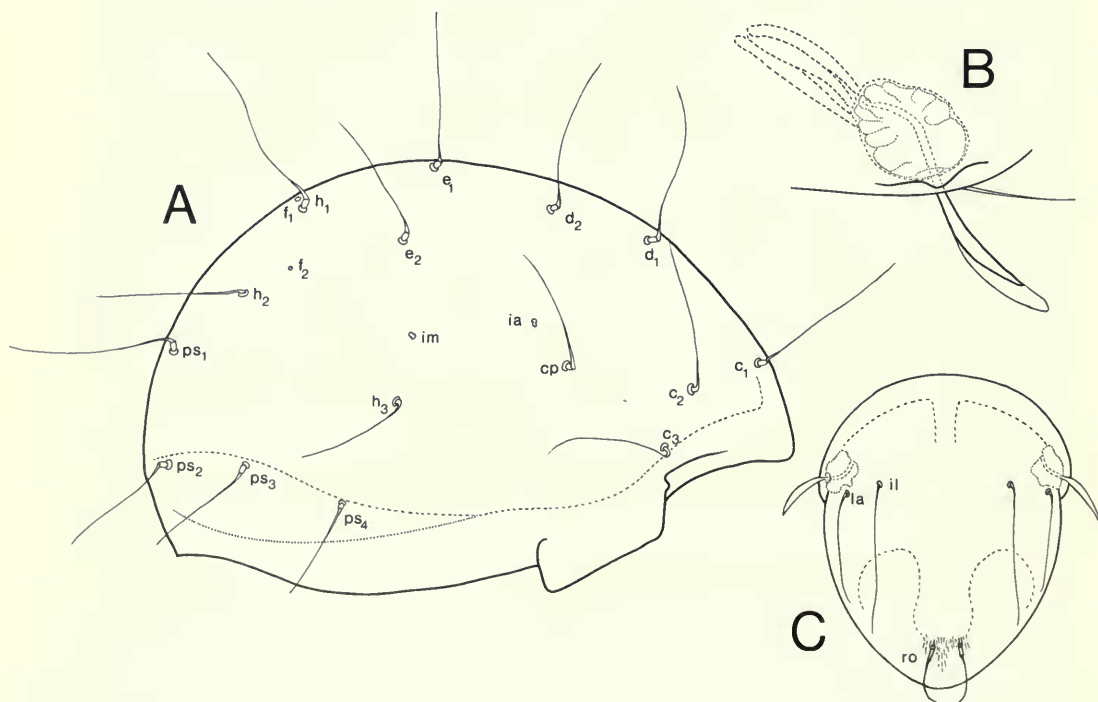


Fig. 8 *Phthiracarus globus*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal.

REMARKS: In comparison with the other 'reduced chaetotaxy' species examined, *P. flexisetosus* is rather large and the interlamellar and notogastral setae are much longer.

*Phthiracarus globus* sp. nov.

(Figs 8; 9; Pl. 4a)

ADULT (Pl. 4a): Large and moderately sclerotized. The *aspis* (Fig. 8C) ranges in length from 324–365  $\mu\text{m}$  with a greatest width of 263–294  $\mu\text{m}$ . All the dorsal setae are moderately long and fine. Setae (*il*) are about 1.5 times the length of setae (*la*) and almost reach the level of the rostrals. The latter extend beyond the anterior margin of the aspis. The sensillus (Fig. 8B) is 50–60  $\mu\text{m}$  long, lanceolate and serrated. It closely resembles that found in *P. affinis*. The *notogaster* (Fig. 8A), 578–852  $\mu\text{m}$  long and with a greatest depth of 426–553  $\mu\text{m}$ , is globular in lateral aspect. All the setae are long (more than the distance  $c_1 - d_1$ ), fine and almost erect. Seta  $c_3$  is inserted on the posterior margin of the collar and setae  $c_{1-2}$  submarginally. Vestigial  $f_1$  is located adjacent to seta  $h_1$  and towards the mid-dorsal line. In one paratype  $f_1$  is located a short distance posterior to seta  $h_1$ . The fissures *ip* and *ips* are absent. On each *anal plate* there are five long setae;  $an_{1-2}$  and  $ad_3$  being more or less equal in length and somewhat shorter than  $ad_{1-2}$ . The *chelicerae* are approximately 208  $\mu\text{m}$  long. The principal segment carries about 26 sharply pointed spines on the paraxial surface and about 24 conical spines antiaxially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1-4-2-5-16-1); II (1-3-2-3-12-1); III (2-2-1-2-10-1) and

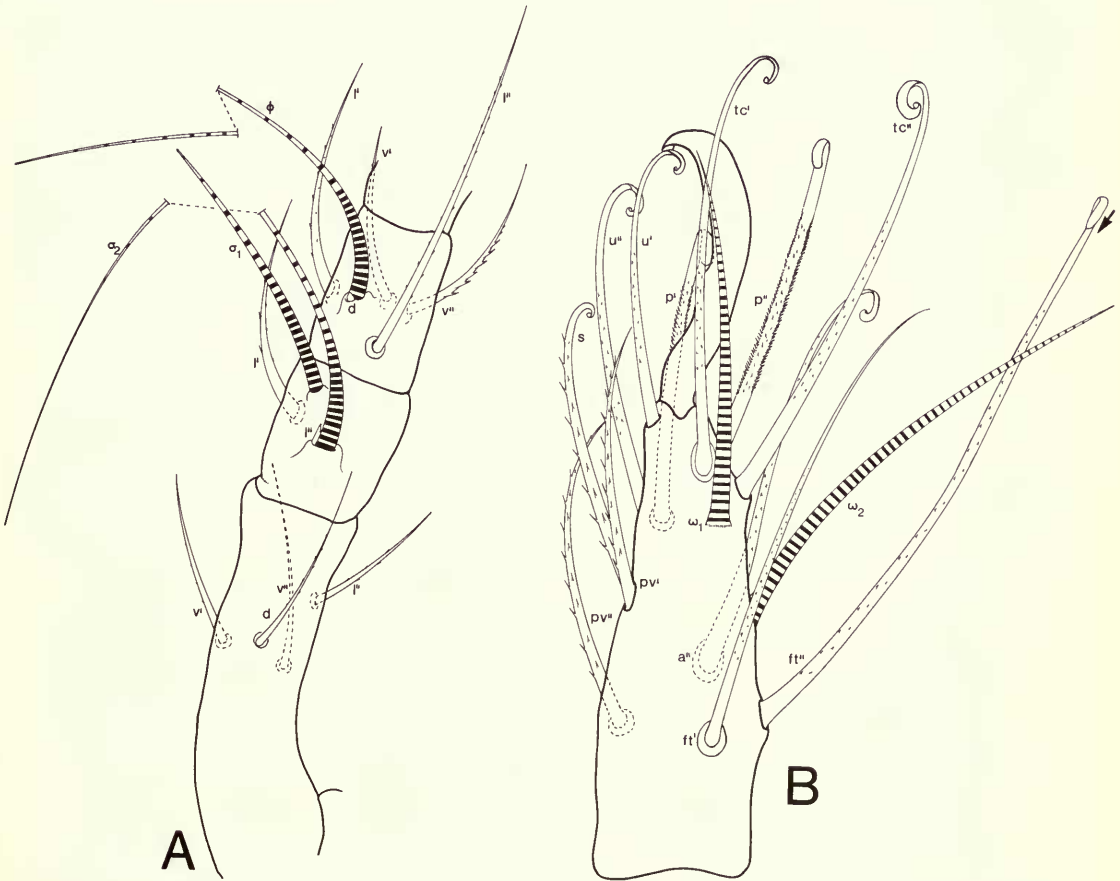


Fig. 9 *Phthiracarus globus*: (A) leg I, trochanter to tibia, dorsal aspect; (B) tarsus II, anterolateral aspect.

IV (2-1-1-2-10-1). Seta *d* on femur I is long, straight and only weakly serrated (Fig. 9A). On tarsus II (Fig. 9B) seta *fi*" is hooked distally.

**TYPES:** Holotype, BMNH reg. no. 1976.2.18.3, from mosses and liverworts on rocks, Rydal Water, Westmorland, 29.i.54 (P. N. Lawrence). Two paratypes, 1976.2.18.4-5, from mosses, Long Compton Woods, Warwickshire, 15.viii.51 (P. N. Lawrence).

**DISTRIBUTION:** *P. globus* was also recorded in small numbers in the F and H layers under beech and oak at each of the study areas (see p. 324). Other material was examined from Wytham Woods Estate, Berkshire, 28.ix.70 (T. G. Wood) and from Woodwalton Fen, Huntingdonshire, 20.v.65 (P. N. Lawrence).

**REMARKS:** Of the 'complete chaetotaxy' species examined, *P. globus* is somewhat unusual in bearing *f*<sub>1</sub> adjacent to *h*<sub>1</sub>, a feature generally associated with those species having the 'reduced chaetotaxy' combination.

*P. globus* is similar to *P. clavatus*. However, in contrast to the latter, the sensillus of *P. globus* is lanceolate and the notogastral setae are distinctly procurved. Moreover, in *P. globus* vestigial *f*<sub>1</sub> is located much closer to the seta *h*<sub>1</sub>.

***Phthiracarus juvenalis* sp. nov.**  
(Fig. 10A-C; Pl. 4b, d)

**ADULT** (Pl. 4b): Medium-sized and weakly sclerotized. The *aspis* (Fig. 10C) ranges in length from 258-279 µm with a greatest width of 213-223 µm. All the dorsal setae are moderately long and fine. Setae (*il*) are about 1.5 times the length of setae (*la*) and equal to the distance *il-ro*. The latter do not reach the anterior margin of the aspis. The sensillus (Fig. 10B; Pl. 4d) is rather long (80 µm), narrow and pointed distally. The tracheoles are short and finger-like. The *notogaster* (Fig. 10A) ranges in length from 558-588 µm with a greatest depth of 365-406 µm. All the setae are short (less than the distance *c*<sub>1</sub>-*d*<sub>1</sub>), fine and directed posteriorly. Setae *c*<sub>1</sub> and *c*<sub>3</sub> are inserted close to the posterior margin of the collar and seta *c*<sub>2</sub> submarginally. Vestigial *f*<sub>1</sub> is located a short distance posterior to seta *h*<sub>1</sub>. The fissures *ip* and *ips* are absent. On each *anal plate* there are two setae in the anal series and one in the adanal series; all are moderately long and more or less equal in length. The *chelicerae* are approximately 152 µm long. The principal segment carries about 19 sharply pointed spines on the paraxial surface and about 15 conical spines antiaxially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1-4-2-5-16-1); II (1-3-2-3-12-1); III (2-2-1-2-10-1) and IV (2-1-1-2-10-1).

**TYPES:** Holotype, BMNH reg. no. 1976.2.18.6, and one paratype, 1976.2.18.7, from leaf litter, Higher Kiln Quarry, Buckfastleigh, Devon, 25.iv.64 (C. Moreby).

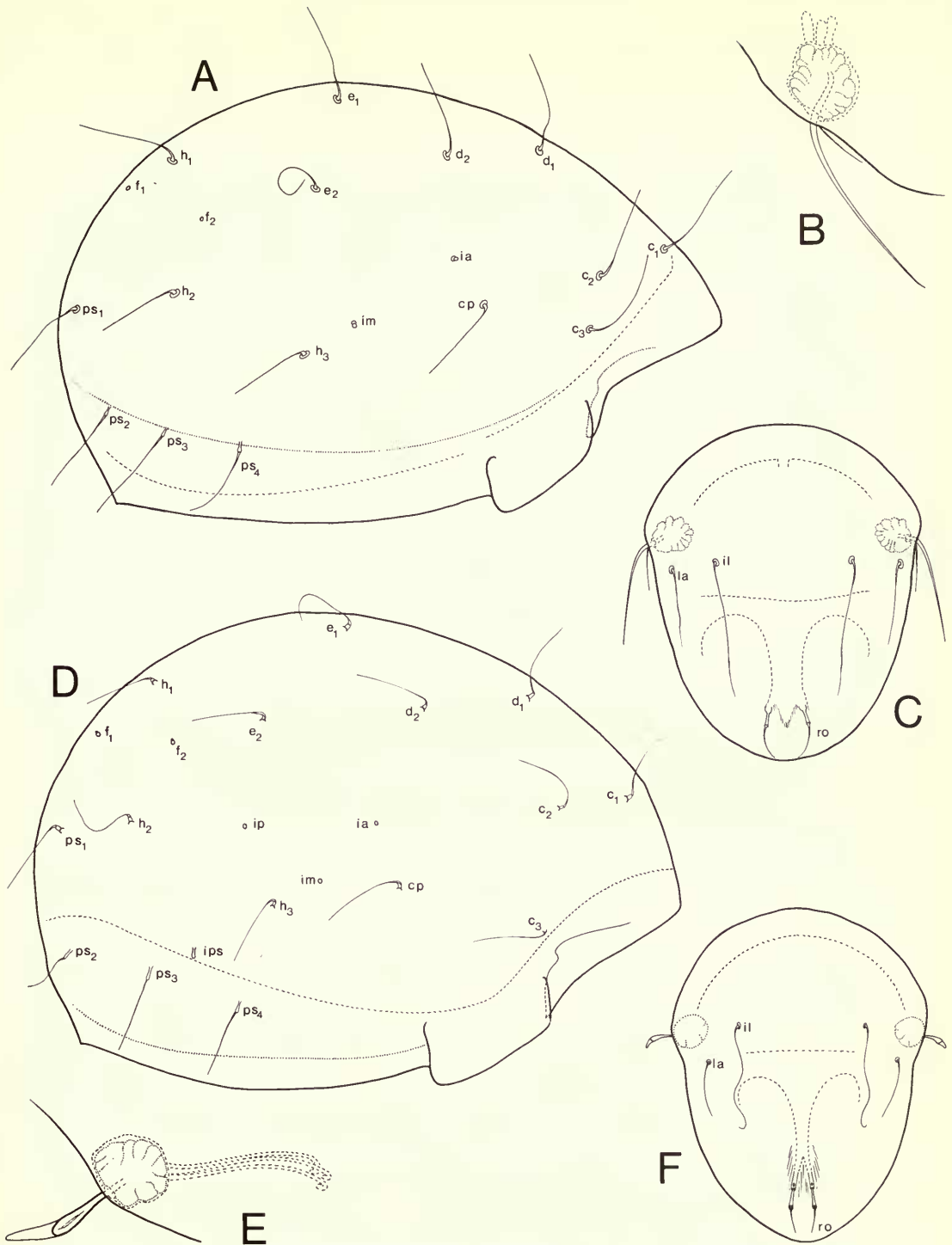
**DISTRIBUTION:** Common in moor forest soils. *P. juvenalis* was recorded under both the hardwood and coniferous tree species at each of the study areas (see p. 324) being particularly abundant in beech and oak F where it accounted for 5-15% of the euptyctimoid population. Other material was examined from Woodwalton Fen, Huntingdonshire, 20.v.65 (P. N. Lawrence) and from Castor Hanglands, Northamptonshire, 21.vi.63 (P. N. Lawrence).

**REMARKS:** Of the species examined with a 'complete chaetotaxy', *P. juvenalis* is the only one to possess a rather long sensillus and backwardly directed notogastral setae.

*P. ligneus*, recorded by Willmann (1932) in humus, moist *Juncus* and moss on the Dummersdorf bank, River Trave, West Germany, shows an overall similarity to *P. juvenalis*. The syntype series (five specimens mounted in Canada Balsam) has been examined, and in comparison to *P. juvenalis* the specimens found to be much smaller (notogastral length 375-420 µm) while the notogastral setae and the sensilli are distinctly longer than in *P. juvenalis*.

*P. juvenalis* also resembles two recently described species, *P. clemens* Aoki 1963 from Tokyo and *P. crispus* Hammer 1972 from Tahiti. However, in comparison with *P. juvenalis*, topotypes of *P. clemens* were found to be larger (notogastral length about 700 µm) while the holotype of *P. crispus* was much smaller (notogastral length about 430 µm). Moreover, in contrast to *P. juvenalis*, the notogastral setae of both species are procurved.





**Fig. 10A–C** *Phthiracarus juvenalis*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal.

**Fig. 10D–F** *Phthiracarus laevigatus*: (D) notogaster, lateral; (E) sensillus and bothridium; (F) aspis, dorsal.

*Phthiracarus laevigatus* (C. L. Koch)

(Fig. 10D–F; Pl. 4e)

*Hoplophora laevigata* Koch, 1841: Fasc. 38 t.16; 1842: 116.*Phthiracarus laevigatus*: Jacot, 1936: 167; van der Hammen, 1963: 704 (neotype designated).

ADULT: Large and strongly sclerotized. The *aspis* (Fig. 10F) ranges in length from 406–456  $\mu\text{m}$  with a greatest width of 355–400  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il*–*ro*. The sensillus (Fig. 10E) is about 50  $\mu\text{m}$  long, narrow and finely serrated. The *notogaster* (Fig. 10D) ranges in length from 812–1065  $\mu\text{m}$  with a greatest depth of 521–771  $\mu\text{m}$ , and in lateral view is seen to be sharply angled at the level of seta  $c_1$  (Pl. 4e). The latter is inserted relatively far back. All the setae are short (less than the distance  $c_1$ – $d_1$ ), fine and procurved. Vestigial  $f_1$  is located midway between setae  $h_1$  and  $ps_1$ . The fissures *ip* and *ips* are present. On each *anal plate* there are only three setae,  $an_{1-2}$  being much longer than  $ad_3$ . The *leg chaetotaxy* is of the ‘complete type’ with the setal formulae: I(1–4–2–5–16–1); II(1–3–2–3–12–1); III(2–2–1–2–10–1) and IV(2–1–1–2–10–1).

DISTRIBUTION: Three specimens only have been recorded in the British Isles from beech litter, Old Winchester Hill, Hampshire, 1971 (D. R. Kime).

REMARKS: *P. laevigatus* is quite distinctive, being easily recognized by the marked angle of the notogaster at the level of seta  $c_1$ . The leg chaetotaxy is similar to that noted for the other ‘complete chaetotaxy’ species; on tarsus I the solenidion  $\omega_2$  is coupled with a small distal seta, a feature not mentioned by van der Hammen in his redescription. The British material has been compared with the neotype from Regensburg – no morphological differences could be detected.

*P. brevisetae* Jacot, described from decaying grass, Monroe, Connecticut, USA, appears to be close to *P. laevigatus*. The holotype (slide no. 2534h) has been examined and found to be badly damaged. Jacot’s description (Jacot, 1930), however, agrees well with van der Hammen’s (1963) and with the British material, but the attitude of the notogastral setae appears to differ slightly. In *P. laevigatus* the notogastral setae are procurved while in *P. brevisetae* they are directed posteriorly.

*Phthiracarus membranifer* sp. nov.

(Fig. 11A–C)

ADULT: Small and weakly sclerotized. The *aspis* (Fig. 11C) ranges in length from 213–324  $\mu\text{m}$  with a greatest width of 157–243  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il*–*ro*. The latter do not reach the anterior limit of the *aspis*. The sensillus (Fig. 11B) is 70  $\mu\text{m}$  long, narrow, membranous marginally and reminiscent of that of *P. juvenalis*. The tracheoles are short and finger-like. The *notogaster* (Fig. 11A) ranges in length from 314–517  $\mu\text{m}$  with a greatest depth of 223–324  $\mu\text{m}$ . All the setae are relatively long (equal to the distance  $c_1$ – $d_1$ ), fine and almost erect. Setae  $c_1$  and  $c_3$  are situated on the posterior margin of the collar and just anterior to seta  $c_2$ . Vestigial  $f_1$  is located a short distance posterior to seta  $h_1$ . The fissures *ip* and *ips* are absent. On each *anal plate* there are only three setae;  $an_{1-2}$  being much longer than  $ad_3$ . The *chelicerae* are 116–167  $\mu\text{m}$  long. The principal segment carries 9–23 sharply pointed spines on the paraxial surface and 8–20 conical spines antiaxially. The *leg chaetotaxy* is of the ‘reduced type’ with the setal formulae: I (1–3–2–5–15–1); II (1–3–2–3–11–1); III (2–2–1–2–10–1) and IV (2–1–0–2–9–1). On tarsus I seta  $u'$  is short, thick and resembles a eupathidium. In one paratype the ‘complete chaetotaxy’ condition of tarsi I to IV (16, 12, 10 and 10) is associated with a ‘reduced chaetotaxy’ condition on femur I (3) and genu IV (0).

TYPES: Holotype, BMNH reg. no. 1976.2.18.14, and two paratypes, 1976.2.18.15–16, from Sitka spruce F, Tintern Forest, Monmouthshire, 4.vi.73 (B. W. Parry).

DISTRIBUTION: *P. membranifer* was also recorded from Higher Kiln Quarry, Devon, 25.iv.64 (C. Moreby) and from Torboll, Sutherland, 29.vi.76 (P. D. Hillyard). This species was not abundant in any of the samples examined.

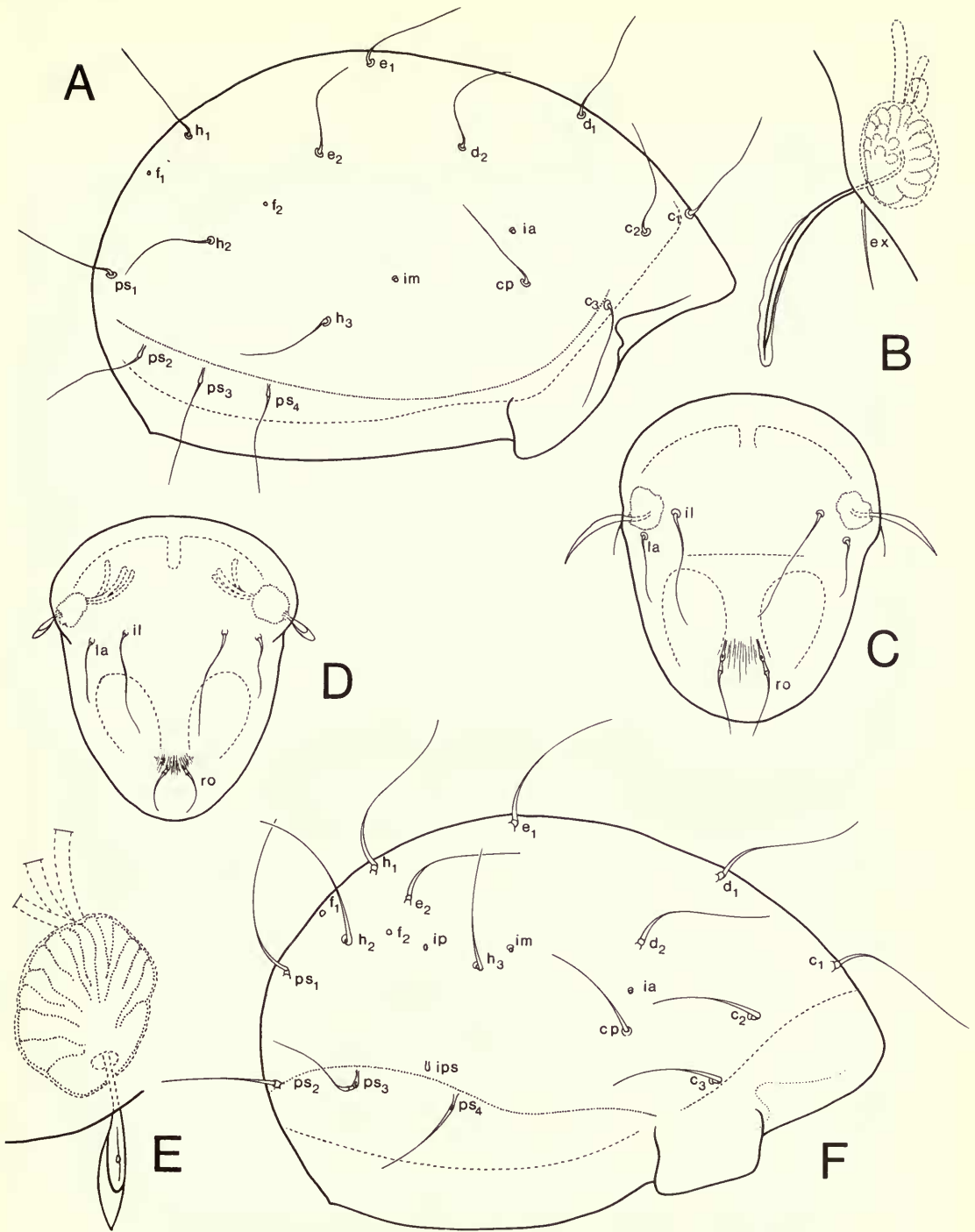


Fig. 11A–C *Phthiracarus membranifer*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal.

Fig. 11D–F *Phthiracarus murphyi*: (D) aspis, dorsal; (E) sensillus and bothridium; (F) notogaster, lateral.

REMARKS: The smallest of the British species examined, *P. membranifer* is somewhat unusual in bearing vestigial  $f_1$  posterior to the seta  $h_1$  (a feature generally associated with the larger 'complete chaetotaxy' species).

*Phthiracarus murphyi* Harding

(Fig. 11D–F; Pl. 4c)

*Phthiracarus murphyi* Harding, 1976 : 164.

ADULT (Pl. 4c): Large and strongly sclerotized. The *aspis* (Fig. 11D) is about 300  $\mu\text{m}$  in length with a greatest width of about 250  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il*–*ro*. Setae (*ro*) do not reach the anterior limit of the aspis. The sensillus (Fig. 11E) is short (40–50  $\mu\text{m}$ ), ovate and serrated. The *notogaster* (Fig. 11F) is about 700  $\mu\text{m}$  in length with a greatest depth of about 420  $\mu\text{m}$ . All the setae are relatively long (equal to the distance  $c_1 - d_1$ ) and markedly procurved. Seta  $c_3$  is inserted on the posterior collar margin and setae  $c_{1-2}$  submarginally. Vestigial  $f_1$  is located midway between setae  $h_1$  and  $ps_1$ . The fissures *ip* and *ips* are present. On each *anal plate* there are five long setae;  $an_{1-2}$  and  $ad_3$  being more or less equal in length and somewhat shorter than  $ad_{1-2}$ . The *chelicerae* are approximately 213  $\mu\text{m}$  in length. The principal segment carries about 18 sharply pointed spines on the paraxial surface and about 16 conical spines antiaxially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1–4–2–5–16–1); II (1–3–2–3–12–1); III (2–2–1–2–10–1) and IV (2–1–1–2–10–1). On tarsus I the distal seta coupled with solenidion  $\omega_2$  is rather short. Seta *fi*" on tarsus II is hooked distally.

DISTRIBUTION: This species was collected in small numbers from Wytham Woods Estate, Berkshire, 28.x.70 (T. G. Wood) and from Torboll, Sutherland, 29.vi.76 (P. D. Hillyard).

REMARKS: Although rather larger, *P. murphyi* appears to bear some resemblance to *P. insularis* Jacot (notogastral length about 500  $\mu\text{m}$ ) recorded from Teuanui, Tovii, the Marquesas Islands. Jacot (1935) did not refer in his description to the fissures *ip* and *ips* although his figure shows quite clearly that these fissures are present. In comparison with *P. murphyi*, the notogastral setae of *insularis* appear to be shorter (less than the distance  $c_1 - d_1$ ). Unfortunately, the 'cotype' of *P. insularis* is apparently lost.

*Phthiracarus nitens* (Nicolet)

(Fig. 12A–C)

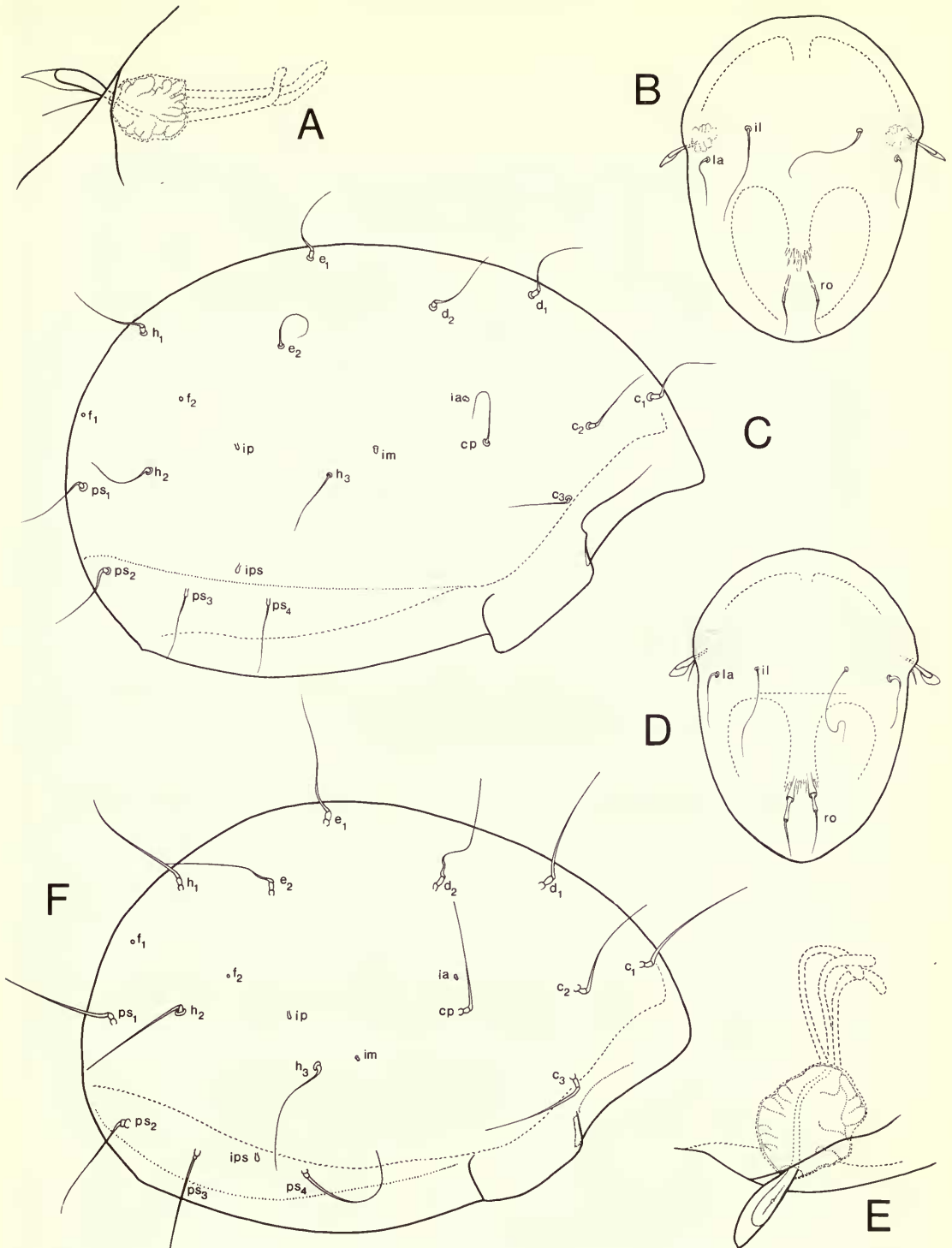
*Hoplophora nitens* Nicolet, 1855 : 472.

*Phthiracarus nitens*: van der Hammen, 1964 : 400 (neotype designated).

ADULT: Large and moderately sclerotized. The *aspis* (Fig. 12B) ranges in length from 253–460  $\mu\text{m}$  with a greatest width of 213–360  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il*–*ro*. The sensillus (Fig. 12A) is 50–60  $\mu\text{m}$  in length, narrow and resembles that of *P. laevigatus*. The *notogaster* (Fig. 12C) ranges in length from 502–900  $\mu\text{m}$  with a greatest depth of 299–600  $\mu\text{m}$ . All the setae are short (less than the distance  $c_1 - d_1$ ), fine and procurved. Seta  $c_3$  is inserted on the posterior margin of the collar and setae  $c_{1-2}$  submarginally. Vestigial  $f_1$  is located midway between setae  $h_1$  and  $ps_1$ . The fissures *ip* and *ips* are present. On each *anal plate* there are only three setae;  $an_{1-2}$  being much longer than  $ad_3$ . The *chelicerae* are approximately 270  $\mu\text{m}$  long. The principal segment carries 17–21 sharply pointed spines on the paraxial surface and 10–19 conical spines antiaxially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1–4–2–5–16–1); II (1–3–2–3–12–1); III (2–2–1–2–10–1) and IV (2–1–1–2–10–1). On tarsus II seta *fi*" is hooked distally.

DISTRIBUTION: *P. nitens* was collected in small numbers from the following localities: Wytham Woods Estate, Berkshire, 28.x.70 (T. G. Wood); St Agnes, Isles of Scilly, Cornwall, 5.iv.57 (K. H. Hyatt); Higher Kiln Quarry, Devon, 25.iv.64 (C. Moreby); Tring Deer Park, Hertfordshire, 1.ii.64 (P. N. Lawrence).





**Fig. 12A–C** *Phthiracarus nitens*: (A) sensillus and bothridium; (B) aspis, dorsal; (C) notogaster, lateral.

**Fig. 12D–F** *Phthiracarus rectisetosus*: (D) aspis, dorsal; (E) sensillus and bothridium; (F) notogaster, lateral.

REMARKS: The neotype from Regensburg has been examined and in comparison with the British material the notogastral setae appear to be somewhat longer. The leg chaetotaxy is of the 'complete type'. On tarsus I the solenidion  $\omega_2$  is coupled with a short distal seta and on tarsus II the posterior fastigial seta is hooked distally. Neither of these features was noted by van der Hammen in his redescription.

*P. nitens* is similar to if not conspecific with *P. montanus* recorded by Pérez-Iñigo in grassland soil and moist moss, Sierra de Guadarrama, Spain. The holotype was examined and seen to be cleared but undissected. In comparison with *P. nitens*, it differs only in the form of the distal region of the sensillus which is lobular in *montanus* and pointed in *nitens*.

*Phthiracarus rectisetosus* sp. nov.

(Fig. 12D–F; Pl. 5c)

ADULT (Pl. 5c): Large and strongly sclerotized. The *aspis* (Fig. 12D) ranges in length from 350–477  $\mu\text{m}$  with a greatest width of 268–360  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) which are inserted rather far forward and on a level with setae (*la*) are about 1.5 times the length of the latter and extend two-thirds of the distance *il-ro*. Setae (*ro*) do not reach the anterior limit of the aspis. The sensillus (Fig. 12E) is 40  $\mu\text{m}$  long, ovate, serrated distally and resembles that found in *P. murphyi*. The *notogaster* (Fig. 12F) ranges in length from 710–994  $\mu\text{m}$  with a greatest depth of 482–720  $\mu\text{m}$ . All the setae are relatively long (equal to the distance  $c_1-d_1$ ) and almost erect. Setae  $c_1$  and  $c_3$  are situated on the posterior margin of the collar and seta  $c_2$  submarginally. Vestigial  $f_1$  is located a short distance posterior to seta  $h_1$ . The fissures *ip* and *ips* are present. On each *anal plate* there are five long setae;  $an_{1-2}$  and  $ad_3$  being more or less equal in length and somewhat shorter than  $ad_{1-2}$ . The *chelicerae* are 168–294  $\mu\text{m}$  long. The principal segment carries 22–24 sharply pointed spines on the paraxial surface and 17–22 conical spines anti-axially. The *leg chaetotaxy* is of the 'complete type' with the setal formulae: I (1-4-2-5-16-1); II (1-3-2-3-12-1); III (2-2-1-2-10-1) and IV (2-1-1-2-10-1). On tarsus I the distal seta coupled with solenidion  $\omega_2$  is almost as long as the famulus. Seta *ft*" on tarsus II is hooked distally.

TYPES: HOLOTYPE, BMNH reg. no. 1976.2.18.8, and one paratype, 1976.2.18.9, from beech litter, Burnham Beeches, Buckinghamshire, 1964 (G. O. Evans). Two paratypes, 1976.2.18.10–11, from beech F, Wytham Woods Estate, Berkshire, 28.ix.70 (T. G. Wood).

DISTRIBUTION: Common in mor soils particularly under beech. *P. rectisetosus* is evidently widely distributed in the British Isles and was abundant in all the samples examined from Monks Wood, Cambridgeshire, 16.v.75 (J. A. Moffat); Woodbastwick Marshes, Norfolk, 10.vii.74 (S. J. Moore); West Allendale, Northumberland, 18.ix.75 (R. M. Emberson); Long Compton Woods, Warwickshire, 15.viii.51 (P. N. Lawrence); Hag Wood, Yorkshire, 12.iv.71 (D. R. Kime); Newtonmore, Inverness-shire, 3.vii.73 (M. J. Bishop); Lochdonhead and Tobermory, Mull, 28.v.70 (P. N. Lawrence); Torboll, Sutherland, 29.vi.76 (P. D. Hillyard); Llanthony, Monmouthshire, i.iv.73 (M. J. Bishop).

REMARKS: *P. rectisetosus* bears some resemblance to two other 'complete chaetotaxy' species, namely *P. clavatus* and *P. globus*. However, *P. rectisetosus* bears four pairs of lateral fissures while *P. clavatus* and *P. globus* bear only two pairs.

*Phthiracarus serrulatus* sp. nov.

(Fig. 13A–C; Pl. 5b)

ADULT (Pl. 5b): Small and weakly sclerotized. The *aspis* (Fig. 13C) ranges in length from 182–213  $\mu\text{m}$  with a greatest width of 137–157  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il-ro*. The rostrals which are inserted relatively far apart do not reach the anterior limit of the aspis. The sensillus (Fig. 13B) is long (70  $\mu\text{m}$ ), narrow and tapers to a point distally with three or four straight-edged teeth subterminally. The tracheoles are short and finger-like. The *notogaster* (Fig. 13A) ranges in length from 456–466  $\mu\text{m}$  with a greatest depth of 324–334  $\mu\text{m}$ . All the

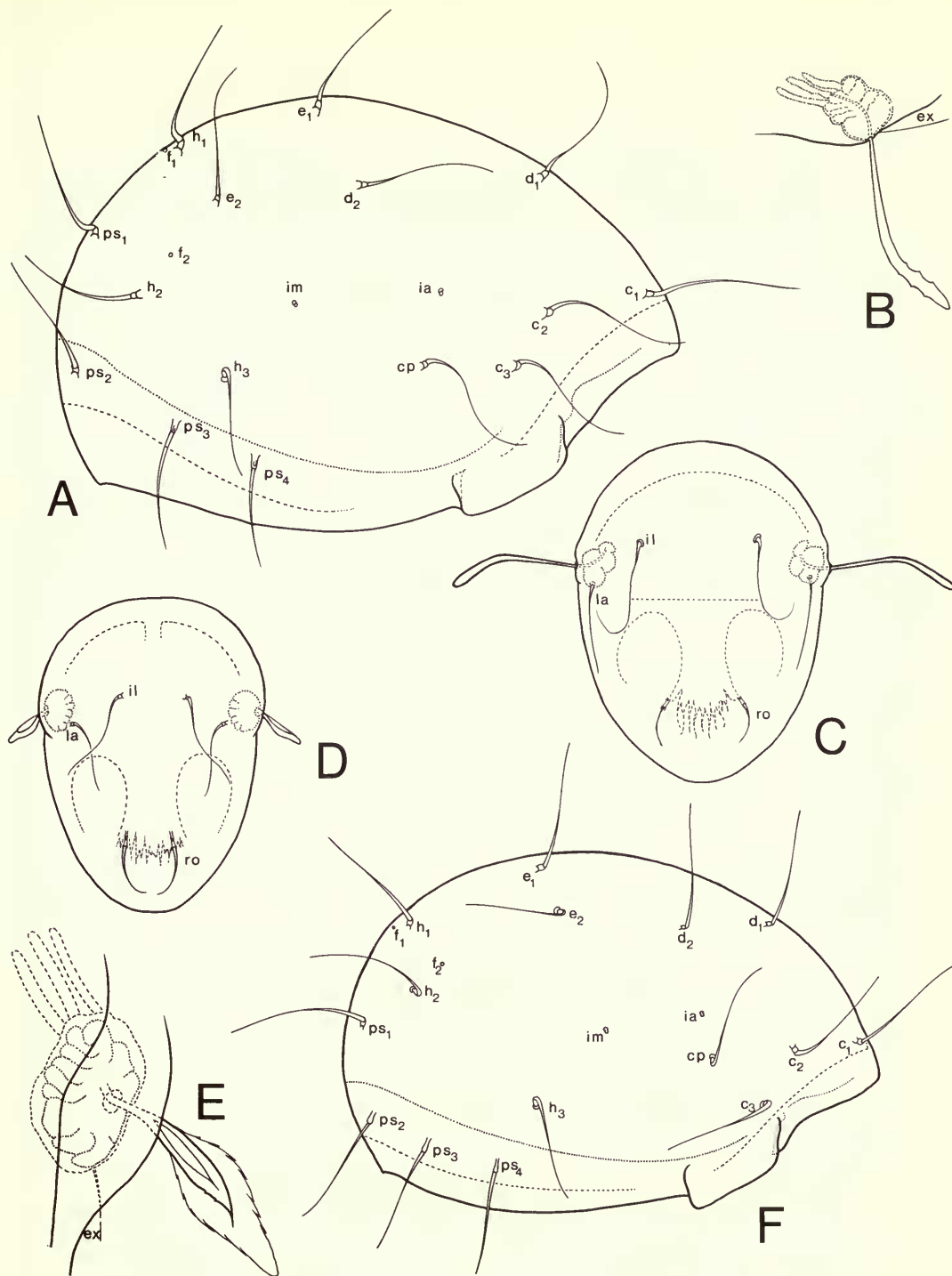


Fig. 13A–C *Phthiracarus serrulatus*: (A) notogaster, lateral; (B) sensillus and bothridium; (C) aspis, dorsal.

Fig. 13D–F *Phthiracarus tardus*: (D) aspis, dorsal; (E) sensillus and bothridium; (F) notogaster, lateral.

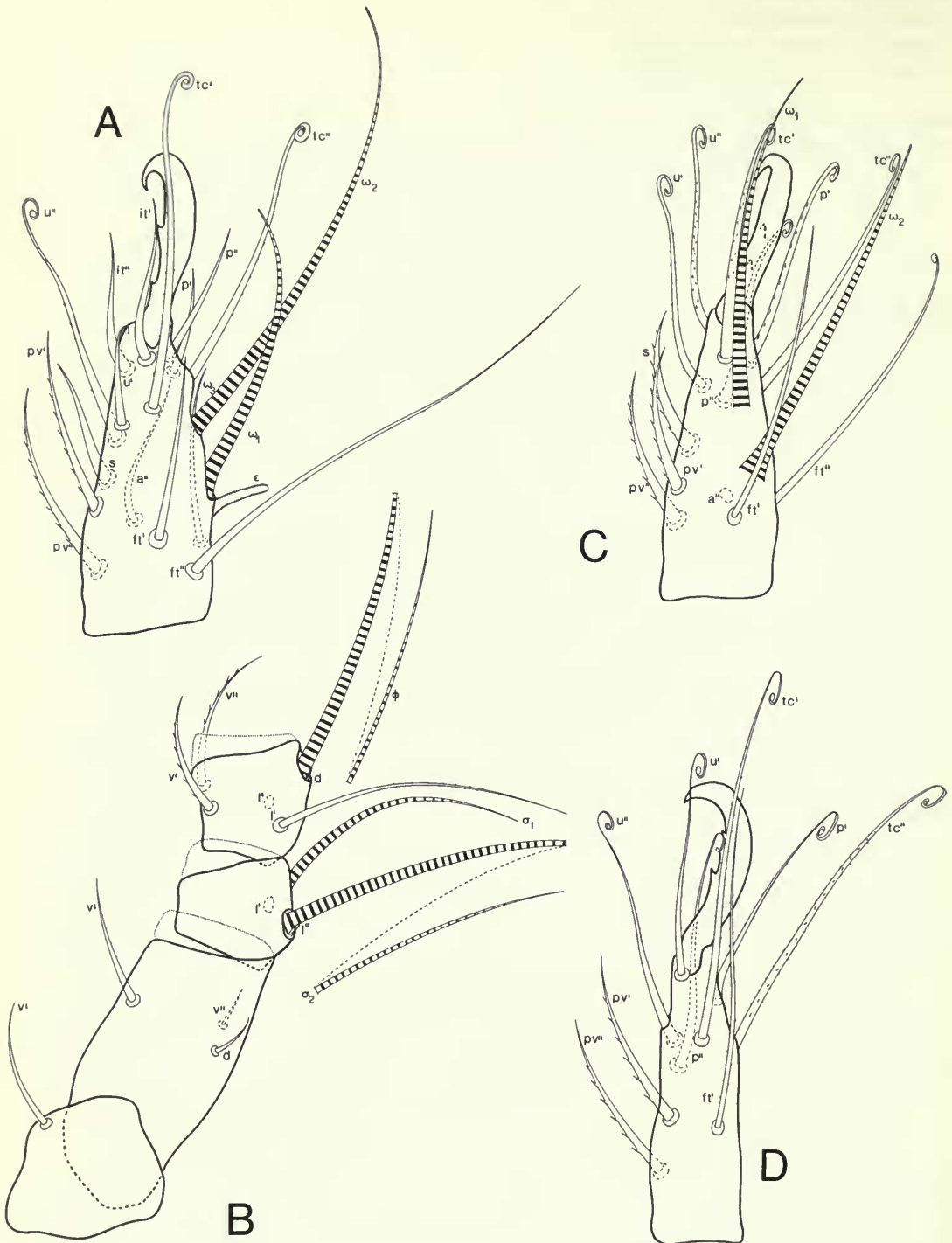


Fig. 14 *Phthiracarus tardus*, anterolateral aspect of legs I, II and IV: (A) tarsus I; (B) leg I, trochanter to tibia; (C) tarsus II; (D) tarsus IV. (Fig. 14A–D are drawn at the same magnification.)



setae are relatively long (equal to the distance  $c_1 - d_1$ ), fine and procurved. Seta  $c_1$  is inserted on the posterior collar margin and setae  $c_{2-3}$  submarginally. Vestigial  $f_1$  is located adjacent to seta  $h_1$  and towards the mid-dorsal line. The fissures *ip* and *ips* are absent. On each *anal plate* there are two setae in the anal series and one in the adanal series – all are moderately long and more or less equal in length. The *chelicerae* are approximately 120  $\mu\text{m}$  long. The principal segment carries about 17 sharply pointed spines on the paraxial surface and about 16 conical spines antiaxially. The *leg chaetotaxy* is of the 'reduced type' with the setal formulae: I (1–3–2–5–15–1); II (1–3–2–3–11–1); III (2–2–1–2–10–1) and IV (2–1–0–2–9–1).

**TYPES:** Holotype, BMNH reg. no. 1976.2.18.12, and one paratype, 1976.2.18.13, from beech F, Wytham Woods Estate, Berkshire, 28.ix.70 (T. G. Wood). *P. serrulatus* is only known from the type locality.

**REMARKS:** *P. serrulatus* shows an overall similarity to *P. minimarginatus* Woolley 1954, a species described from Colorado, USA. However, in comparison with *serrulatus*, the holotype of *minimarginatus* (dissected, partially cleared and mounted in Berlese's fluid) was found to possess shorter notogastral setae while vestigial  $f_1$  was located midway between setae  $h_1$  and  $ps_1$ . Moreover, the sensillus of the American species was found to bear many more distal serrations than that of *P. serrulatus*. Both species are of a similar size (about 450  $\mu\text{m}$ ).

***Phthiracarus tardus* Forsslund**  
(Figs 13D–F; 14; Pl. 5a, d)

*Phthiracarus tardus* Forsslund, 1956 : 216.

**ADULT** (Pl. 5a): Small and weakly sclerotized. The *aspis* (Fig. 13D) is about 223  $\mu\text{m}$  in length with a greatest width of about 187  $\mu\text{m}$ . All the dorsal setae are fine and short. Setae (*il*) are about 1.5 times the length of setae (*la*) and extend two-thirds of the distance *il-ro*. The rostrals which are inserted relatively far apart do not reach the anterior limit of the aspis. The sensillus (Fig. 13E; Pl. 5d) is 30–40  $\mu\text{m}$  in length and broadly clavate. The *notogaster* (Fig. 13F) is about 497  $\mu\text{m}$  in length with a greatest depth of about 314  $\mu\text{m}$ . All the setae are relatively long (equal to the distance  $c_1 - d_1$ ), fine and erect. Setae  $c_{1-3}$  form a row just behind the posterior margin of the collar. Vestigial  $f_1$  is located adjacent to seta  $h_1$  and towards the mid-dorsal line. The fissures *ip* and *ips* are absent. On each *anal plate* there are only three setae;  $an_{1-2}$  being much longer than  $ad_3$ . The *chelicerae* are approximately 147  $\mu\text{m}$  long. The principal segment carries about 16 sharply pointed spines on the paraxial surface and about 9 conical spines antiaxially. The *leg chaetotaxy* (Fig. 14) is of the 'reduced type' with the setal formulae: I (1–3–2–5–15–1); II (1–3–2–3–12–1); III (2–2–1–2–10–1) and IV (2–1–0–2–9–1). On tarsus I seta  $u'$  is short, thick and resembles a eupathidium. Seta  $f_1''$  on tarsus II is hooked distally and this segment carries a subunguinal seta  $s$ .

**DISTRIBUTION:** Only a small number of specimens have been recorded in the British Isles from mull soil, Meathop Wood, Westmorland, 19.iii.63 (P. N. Lawrence).

**REMARKS:** *P. tardus* is somewhat unusual in bearing 12 setae on tarsus II and by having a hooked posterior fastigial seta on this segment (both features are generally associated with 'complete chaetotaxy' species).

A comparison of British and paratype material revealed no morphological differences.

### 'Complete' and 'reduced' leg chaetotaxy – a possible basis for a subdivision of the genus *Phthiracarus*

The earliest proposed subdivision of the genus *Phthiracarus* appears to be that of Feider and Suciu (1957) who recognized two species groups based solely on the shape of the sensillus. Their 'anonymum group' included species with spindle-shaped sensilli (*anonymum*, *globosus*, *lanatus* and *piger*) and their 'lentulus group' species with thread-like sensilli (*baloghi*, *italicus*, *lentulus*, *ligneus*,

*parabotrichus* and *sellnicki*). However, these do not appear to be satisfactory groupings since the present study has suggested that sensillar shape is not correlated with other features, such as the chaetotactic pattern of the legs or notogaster.

Eight years later and based on a study of three species, van der Hammen (1965) suggested that the number of notogastral fissures, the position of the vestigial seta  $f_1$ , the number of adanal setae and the chaetotactic pattern of the legs were features which could be used in a future subdivision of the genus, and placed *P. laevigatus* and *P. nitens* (*ip* and *ips* present;  $f_1$  ventral to  $h_1$ ;  $ad_{1-2}$  absent; femur I with four setae; genu IV with a single seta) in a separate group from *P. anonymum* (*ip* and *ips* absent;  $f_1$  dorsal to  $h_1$ ;  $ad_{1-2}$  present; femur I with three setae; genu IV without any setae). Although the number of adanal setae has been found to be uncorrelated with other morphological features, the present study supports van der Hammen's proposed division of the genus on the remaining characters. Of the eight British species having the combination 'femur I-4, genu IV-1', only *murphyi* and *rectisetosus* have all the attributes of van der Hammen's 'laevigatus-nitens group', since the other species (*affinis*, *clavatus*, *globus* and *juvenalis*) all lack the fissures *ip* and *ips*. In the case of species having the combination 'femur I-3, genu IV-0', only *P. anonymum* possesses all the characters of van der Hammen's second grouping.

Using numerical methods, Sheals (1969) examined the affinities of 19 *Phthiracarus* species from Europe, Israel, Labrador and Morocco, recognizing three species groups based on the following combinations of characters: femur I-4, genu IV-1, fissure *ips* present; femur I-4, genu IV-1, fissure *ips* absent; femur I-3, genu IV-0, fissure *ips* absent. It is noteworthy that *P. anonymum* which in the present study was found to be rather atypical, formed part of a reasonably compact cluster of five species in this grouping studied by Sheals (*P. anonymum* and four new species from France, Labrador, Sweden and Switzerland).

The evidence suggests therefore, that morphological differences, particularly in the leg chaetotaxy, could provide a useful basis for dividing this large genus into two species groups. In the present study all the British species (and all the type specimens examined) fell into either a 'complete' (*affinis*, *clavatus*, *globus*, *juvenalis*, *laevigatus*, *murphyi*, *nitens* and *rectisetosus*) or a 'reduced chaetotaxy group' (*anonymum*, *flexisetosus*, *membranifer*, *serrulatus* and *tardus*). In addition to features of the leg chaetotaxy, a number of other characters were also used to distinguish between the two groupings. With the exception of *P. affinis* (notogastral length 406–487  $\mu\text{m}$ ), the species in the 'complete chaetotaxy group' are all rather large (notogastral length 502–1065  $\mu\text{m}$ ). Moreover, in this grouping, the vestigial seta  $f_1$  is generally ventral to seta  $h_1$  while on the aspis the rostral setae are always located rather close together. The fissures *ip* and *ips* are present in some members of the 'complete group' (*laevigatus*, *murphyi*, *nitens* and *rectisetosus*) while they are absent in *affinis*, *clavatus*, *globus* and *juvenalis*. By contrast, species in the 'reduced chaetotaxy group' are all relatively small (notogastral length 314–507  $\mu\text{m}$ ), the fissures *ip* and *ips* are always absent, vestigial  $f_1$  is dorsal or slightly ventral to seta  $h_1$  and on the aspis the rostrals are often located relatively far apart.

Any formal subdivision of the genus will, however, have to be deferred until a new type species has been designated. Van der Hammen (1965) considered *P. contractilis* (type) as being close to his 'laevigatus-nitens group' (and thus to the 'complete chaetotaxy group'), but the type material of *P. contractilis* must be presumed to be lost and Perty's original description is such as to make the specific identity of his species impossible. Moreover, on the evidence available from the present study, *P. anonymum* would not be a suitable typical specimen of the 'reduced chaetotaxy group'.

### Acknowledgements

This paper is based substantially on part of a Ph.D. thesis (Parry, 1976) undertaken at the BMNH. The work was supervised jointly by Dr J. G. Sheals, Keeper of Zoology, BMNH, and by Dr J. A. Wallwork of the Zoology Department at Westfield College (University of London). Their valuable advice and encouragement are gratefully acknowledged. Thanks are also due to my colleague, Mr D. Macfarlane, for his comments on the manuscript.

Type material was kindly sent on loan by Dr J. Aoki, National University of Yokohama (NUY),

Dr L. van der Hammen, Rijksmuseum van Natuurlijke Historie (RNH), Leiden and by Dr C. Pérez-Iñigo, Instituto Español de Entomología (IEE), Madrid. Specimens from the Berlese and Willmann Collections were examined through the courtesy of Dr F. Pegazzano, Istituto Sperimentale per la Zoologie Agraria (ISZA), Florence, and Dr W. Hirschmann, Nürnberg respectively. Dr R. E. Crabill, National Museum of Natural History (USNM), Washington, arranged for the loan of type material described by Ewing and Woolley, and Dr H. W. Levi, Museum of Comparative Zoology (MCZ), Cambridge, Massachusetts, allowed me to borrow the type material of Bank's and Jacot's species. Dr J. Travé, Université Pierre et Marie Curie (UPMC), Banyuls-sur-Mer, kindly provided topotypic material of Grandjean's species and Dr S. L. Tuxen, University of Copenhagen Zoological Museum (UZM), sent type material of species described by Marie Hammer. I am grateful to Dr T. G. Wood, formerly of the Animal Ecology Research Group, Oxford, for material collected at Wytham Woods Estate, Berkshire.

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## Appendix 1

### Species described between 1763 and 1977 currently classified in *Phthiracarus*

Species	Date	Type habitat and locality	Type depository*
<i>Hoplodermis affine</i> Hull†	1914	Moss in woods and <i>Sphagnum</i> on moors, West Allendale, Northumberland and Gibside, Durham, England	BMNH, London
<i>Phthiracarus anonymus</i> Grandjean†	1933	Rotting wood in cellar, Périgueux, Dordogne, France	UPMC, Banyuls-sur Mer [Topotype]
<i>Phthiracarus anonyms amicus</i> Jacot†	1938	Deciduous leaf mould, Connecticut Hill, New York, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus apiculatus</i> Jacot	1939	Oak litter in old growth stand, Bent Creek Exp. Forest, North Carolina, USA	[Type series apparently lost]
<i>Phthiracarus baloghi</i> Feider & Suci	1957	Oak leaves, Iași, Rumania	Unknown
<i>Phthiracarus benoiti</i> Balogh	1958	Angola	TM, Budapest
<i>Hoplodermis boreale</i> Trägårdh†	1910	Rotting birch leaves, Sarek, Swedish Lapland	BMNH, London ['Cotype']
<i>Phthiracarus boresetosum</i> Jacot†	1930	Haircap moss in woodland, Cliff Island, Casco Bay, Maine, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus brevisetae</i> Jacot†	1930	Decaying grass at foot of old haystack, East Village, Monroe, Connecticut, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus caudatus</i> Balogh & Mahunka	1977	Moist soil in virgin forest, Estancia Esperanza, Guayaramerin, Bolivia	TM, Budapest
<i>Phthiracarus clemens</i> Aoki†	1963	Imperial Palace Gardens, Tokyo, Japan	NUY, Yokohama [badly broken]
<i>Phthiracarus compressum</i> Jacot†	1930	Upland swamp <i>Sphagnum</i> , East Village, Monroe, Connecticut, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus contractilis</i> Perty‡	1841	Rotting wood, Munich, Augsburg and Passau, West Germany	[Type series apparently lost]
<i>Phthiracarus crenophilus</i> Willmann†	1951	Edge of marsh, Ebreichsdorf, Austria	Hirschmann Coll., Nürnberg

Species	Date	Type habitat and locality	Type depository*
<i>Hoplophora crinita</i> Koch	1841	Moss in woods, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus crispus</i> Hammer†	1972	Rotting leaves and moss (altitude 600 m), Papeete, Tahiti	UZM, Copenhagen
<i>Phthiracarus curtulus</i> Berlese†	1923	Lake City, Florida, USA	ISZA, Florence
<i>Phthiracarus danubianus</i> Feider, Vasilu & Călugăr	1968	Moss and leaves, Cazanele Mici, Rumania	Unknown
<i>Oribates dasypus</i> Dugès‡	1834	Ardennes, France	[Type series apparently lost]
<i>Phthiracarus dubini</i> Feider & Suciu	1958	Hornbeam litter, Constanța, Rumania	Unknown
<i>Phthiracarus feideri</i> Balogh & Csiszár	1963	Litter and moss on bark in marsh forest, Río Negro, El Bolsón, Argentina	TM, Budapest
<i>Hoplophora ferruginea</i> Koch	1841	Moss on trees, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus globifer</i> Hammer†	1962	Meadow near river, Copiapó, Chile	UZM, Copenhagen
<i>Hoplophora globosa</i> Koch	1841	Damp meadows, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus hamatus</i> Hammer†	1973	Dry bark on deciduous tree, Tongatapu Island	UZM, Copenhagen
<i>Phthiracarus insularis</i> Balogh	1962	La Mandraka, Madagascar	TM, Budapest
<i>Phthiracarus insularis</i> Jacot	1935	Dead leaves, Teuanui, Tōvii (altitude 2000 ft), Marquesas Islands	[Type series apparently lost]
<i>Hoploderma italicum</i> Oudemans‡ (= <i>Oribates dasypus</i> Dugès <i>sensu</i> Berlese)	1907	Tiarno, Italy	ISZA, Florence
<i>Phthiracarus jacoti</i> Feider & Suciu	1958	Spruce and fir needles Braşov, Rumania	Unknown
<i>Phthiracarus japonicus</i> Aoki†	1958	Raw humus under conifers, Matsumoto, Japan	NUY, Yokohama [badly broken]
<i>Hoplophora laevigata</i> Koch†	1841	Clubmosses and soil under hedges and bushes, Regensburg area, West Germany	RNH, Leiden [Neotype]
<i>Phthiracarus lanatus</i> Feider & Suciu	1957	Moss, Odorhei, Mureş-Magyar, Rumania	Unknown
<i>Hoplophora lentula</i> Koch	1841	Moss in woods, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus ligneus</i> Willmann†	1932	Humus, moist <i>Juncus</i> and moss on the Dummersdorf bank, River Trave, West Germany	Hirschmann Coll., Nürnberg
<i>Hoplophora longula</i> Koch	1841	Moss in forests, Regensburg area, West Germany	[Type series apparently lost]
<i>Hoplophora lucida</i> Koch	1841	Marshy places in meadows, Regensburg area, West Germany	[Type series apparently lost]
<i>Hoploderma lurida</i> Ewing†	1909	Under bark, Urbana, Illinois, USA	USNM, Washington
<i>Phthiracarus machadoi</i> Balogh	1958	Angola	TM, Budapest
<i>Phthiracarus minimarginatus</i> Woolley†	1954	Moss and grass under aspen, Mount Meeker Camp Ground, Boulder, Colorado, USA	USNM, Washington
<i>Phthiracarus montanus</i> Pérez-Iñigo†	1969	Grassland soil and moist moss, Sierra de Guadarrama, Spain	IEE, Madrid
<i>Phthiracarus montium</i> Jacot	1937	Litter in short-leaf pine stand, Ashville, North Carolina, USA	[Type series apparently lost]

Species	Date	Type habitat and locality	Type depository*
<i>Phthiracarus murphyi</i> Harding†	1976	Beech litter, Lambridge Wood, Oxfordshire, England	BMNH, London
<i>Phthiracarus nigerrimus</i> Berlese†	1920	La Plata, Argentina	ISZA, Florence
<i>Hoplophora nitens</i> Nicolet†	1855	Litter in woods near Paris, France	RNH, Leiden [Neotype]
<i>Phthiracarus olivaceus</i> Jacot†	1928	Soft moist soil, East Village, Monroe, Connecticut, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus pallidus</i> Feider & Suciú	1958	Beech litter, Iași, Rumania	Unknown
<i>Phthiracarus parabotrichus</i> Feider & Suciú	1957	Leaves, Iași and Constanța, Rumania	Unknown
<i>Phthiracarus pavidus minus</i> Krivolutsky	1966	Blagoveschensk, USSR	Unknown
<i>Phthiracarus pellucidus</i> Ramsay	1966	Halophytic scrub and mat plants, Little Brother Island, Cook Strait, New Zealand	DSIR, Nelson & BMNH, London
<i>Phthiracarus peristomaticus</i> Willmann‡	1951	Number of habitats including leaves, turf and subsoil under buckthorn, guelder-rose and alder, near Vienna, Austria	[Type series apparently lost]
<i>Acarus piger</i> Scopoli‡	1763	Encrusting lichens, Carniola ('Karniolie'), Yugoslavia	[Type series apparently lost]
<i>Phthiracarus ponticus</i> Krivolutsky	1975	Unknown	Unknown
<i>Phthiracarus prior</i> Jacot	1933	Gainesville and East Palatka, Florida, USA	[Type series apparently lost]
<i>Phthiracarus pudicus</i> Berlese†	1923	Cape of Good Hope, South Africa	ISZA, Florence
<i>Phthiracarus pygmaeus</i> Balogh	1958	Angola	TM, Budapest
<i>Phthiracarus restrictus</i> Jacot	1937	Litter in rocky cove, Bent Creek Exp. Forest, North Carolina, USA	[Type series apparently lost]
<i>Phthiracarus robertsi</i> Sheals†	1965	Rhododendron litter, Milke Danra, Nepal	BMNH, London
<i>Phthiracarus rotundus</i> Berlese†	1923	Citta di Castello, Italy	ISZA, Florence
<i>Phthiracarus roubali</i> Berlese†	1923	'Boemia (Brady)', possibly Czechoslovakia	ISZA, Florence
<i>Phthiracarus sarahae</i> Jacot†	1930	Spruce needles, Cliff Island, Casco Bay, Maine, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus sellnicki</i> Feider & Suciú	1957	Conifer needles, Brașov and Ploiești, Rumania	Unknown
<i>Phthiracarus serrula</i> Balogh & Mahunka	1977	Gallery forest along River Mamore, Estancia Esperanza, Guayaramerin, Bolivia	TM, Budapest
<i>Phthiracarus setanus</i> Jacot	1939	Litter in laurel slick, Bent Creek, Exp. Forest, North Carolina, USA	[Type series apparently lost]
<i>Hoplophora setosa</i> Banks†	1895	Sea Cliff, New York, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus setosellum</i> Jacot†	1928	Rotten wood and bark slabs, Glen Cove, Long Island, New York, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus setosellum bryobium</i> Jacot*	1930	Upland swamp moss, East Village, Monroe, Connecticut, USA	MCZ, Cambridge, Mass.
<i>Phthiracarus sicilicoma</i> Hammer†	1962	Meadow vegetation under trees, Puerto Montt, Chile	UZM, Copenhagen
<i>Hoplophora sphaerula</i> Banks‡	1895	Sea Cliff, New York, USA	[Type series apparently lost]

Species	Date	Type habitat and locality	Type depository*
<i>Hoplophora straminea</i> Koch	1841	Moss on trees, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus subglobosus</i> Berlese†	1923	Vallombrosa, Italy	ISZA, Florence
<i>Phthiracarus tardus</i> Forsslund†	1956	Humus under <i>Vaccinium</i> in coniferous forest, Degerfors, Västerbotten, Sweden	NR, Stockholm & BMNH, London [Paratype]
<i>Hoplophora testudinea</i> Koch	1841	Moss on trees, Regensburg area, West Germany	[Type series apparently lost]
<i>Phthiracarus torosus</i> Willmann	1939	Leaves, Levado do Inferno, Madeira	[Type series apparently lost]
<i>Phthiracarus tubulus</i> Hammer† (= <i>lapsus calami</i> for <i>Hoplophthiracarus tubulus</i> )	1972	<i>Cyperus</i> litter near coast, Tahiti	UZM, Copenhagen
<i>Phthiracarus undatus</i> Oudemans‡	1915	Paris area, France	[Type series apparently lost]

\* With the following exceptions, DSIR (Department of Scientific and Industrial Research), Nelson, NR (Naturhistoriska Riksmuseet), Stockholm, and TM (Természettudományi Múzeum), Budapest, explanations of depository abbreviations are given with the Acknowledgements.

† Specimens examined during the course of the present study.

‡ Species regarded as *nomina dubia*.

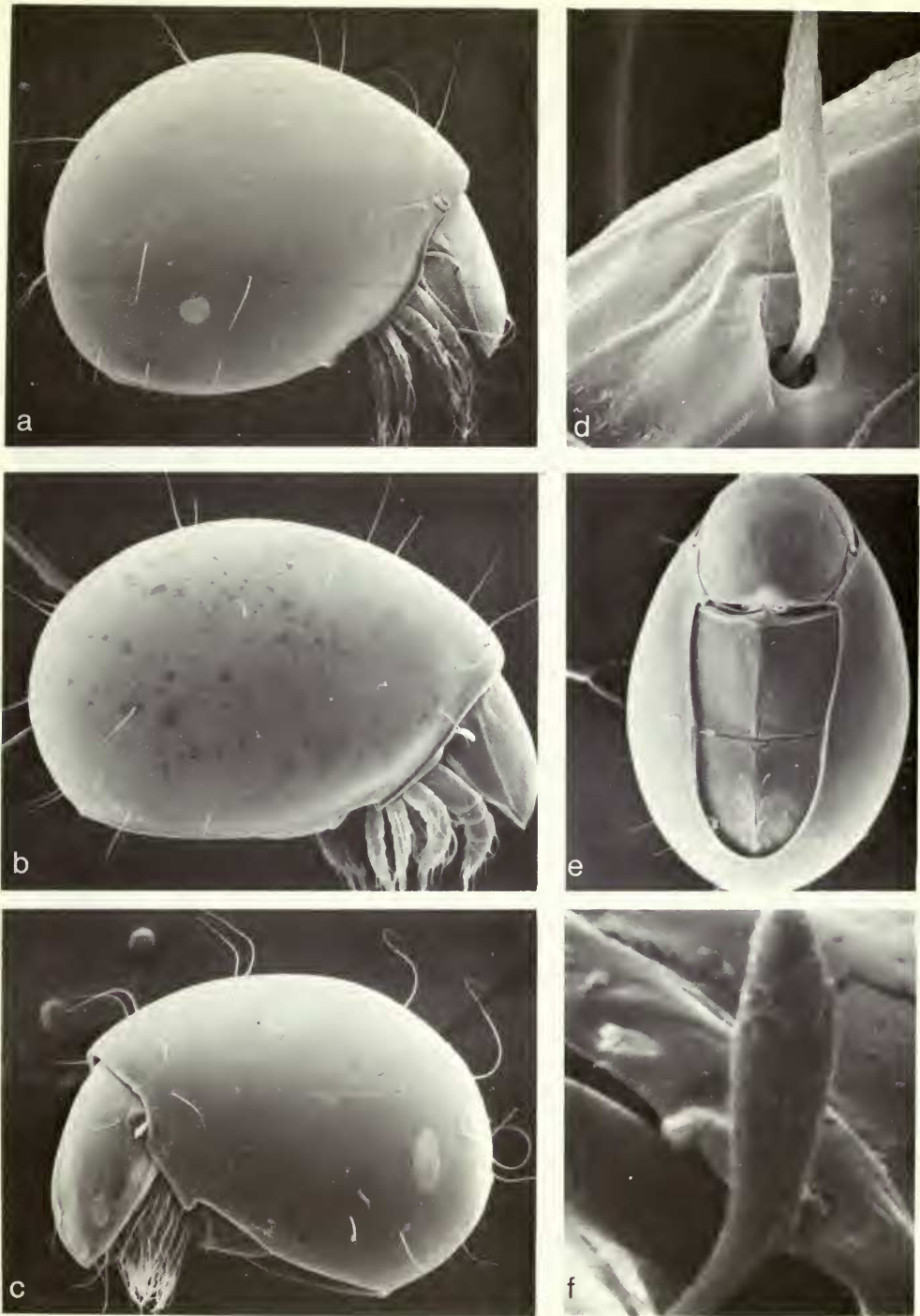




**Plate 1** *Phthiracarus affinis*: idiosomal and gnathosomal features. (a) Sensillus and bothridial scale,  $\times 2400$ . (b) Aggenital seta in furrow of genital plate, anterior aspect,  $\times 1300$ . (c) Adoral setae and rutella, ventral aspect,  $\times 1300$ . (d) Terminal segment of pedipalp showing reduced subultimate seta,  $\times 1450$ . (e) Sensillar notch and thickened bothridial aperture,  $\times 1500$ .

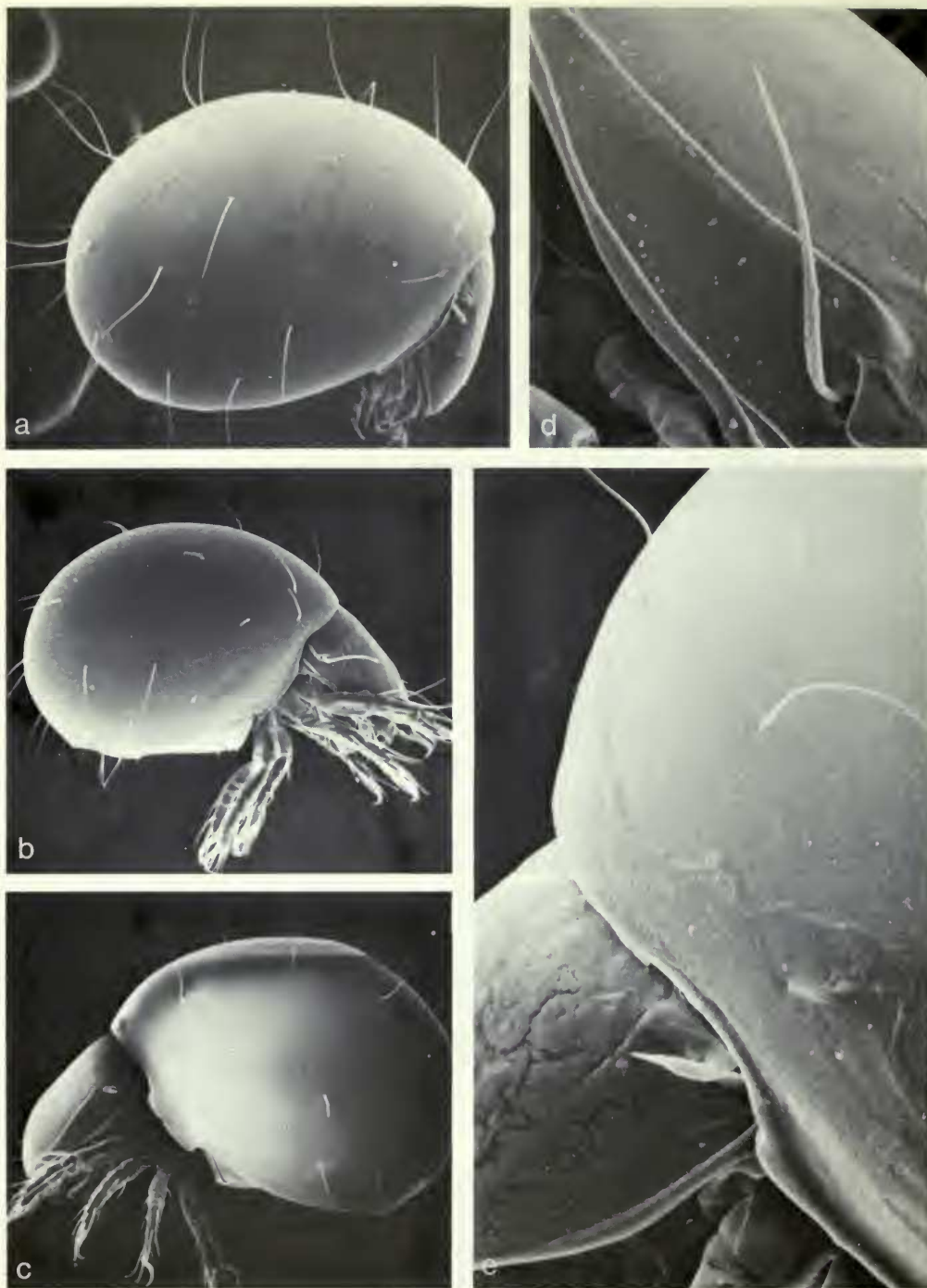


**Plate 2** *Phthiracarus affinis*: legs. (a) Tarsus I, anterolateral aspect,  $\times 1100$ . (b) Distal solenidion and associated seta on tarsus I, posterolateral aspect,  $\times 5100$ . (c) Proximal region of tarsal claw, anterolateral aspect,  $\times 1700$ . (d) Dorsal seta on femur I,  $\times 4800$ . (e) Solenidion and associated seta on tibia II, anterolateral aspect,  $\times 2400$ ; dorsal aspect,  $\times 15\,000$  (shown in inset).



**Plate 3** *Phthiracarus* spp.: (a) *P. affinis*, lateral aspect,  $\times 60$ ; (b) *P. anonymum*, lateral aspect,  $\times 130$ ; (c) *P. clavatus*, lateral aspect,  $\times 100$ ; (d) sensillus of *P. affinis*,  $\times 1500$ ; (e) *P. anonymum*, ventral aspect,  $\times 120$ ; (f) sensillus of *P. clavatus*,  $\times 1900$ .





**Plate 4** *Phthiracarus* spp.: (a) *P. globus*,  $\times 150$ ; (b) *P. juvenalis*,  $\times 80$ ; (c) *P. murphyi*,  $\times 60$ ; (d) sensillus of *P. juvenalis*,  $\times 600$ ; (e) *P. laevigatus*,  $\times 350$ . All mites shown in lateral aspect.





**Plate 5** *Phthiracarus* spp.: (a) *P. tardus*, lateral aspect,  $\times 100$ ; (b) *P. serrulatus*, anterior aspect,  $\times 200$ ; (c) *P. rectisetosus*, lateral aspect,  $\times 60$ ; (d) sensillus of *P. tardus*,  $\times 2600$ .